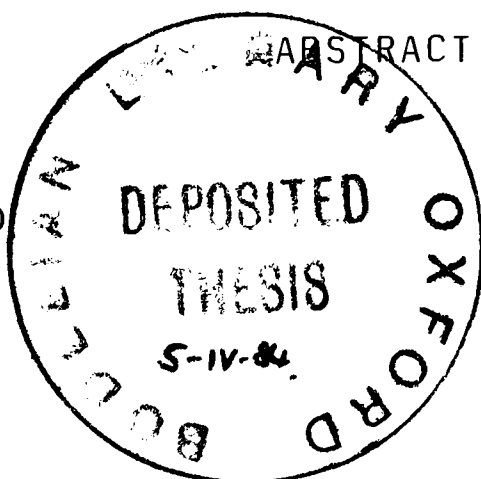


AN ECONOMETRIC INVESTIGATION INTO THE ROLE OF RISK AND
EXPECTATIONS WITH SPECIAL REFERENCE TO STORE LIVESTOCK

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The role of expectations theory and risk perception is examined in relation to the structure of store livestock markets in England and Wales.

Economic and biological features of store production are identified in the beef, dairy, pigs and sheep sectors. The axiomatic base of risk theory is examined and the Expected Utility approach of defining risk is adopted. Allied to the analysis of risk is the role of expectations in store markets. Two major expectations hypotheses are employed which act as a second, and parallel, research investigation to risk in the store markets: Adaptive and Rational Expectations are chosen.

The assumptions and modelling approaches that underlie the analysis are outlined. This then provides a framework in which the influences of risk and expectations are examined.

An ex post analysis of grazing risk is undertaken. Farmers typically under-utilise grazing resources, possibly as a result of the greater risks involved in feeding ruminant stock in this way. It is shown that grassland production, on average, can be intensified without incurring additional risk in terms of more variable output.

The temporal structure of store livestock demand is then investigated on ex ante grounds with subjective risk defined on the basis of the Adaptive Expectations rule. Significant risk responses were found in the store steer, heifer and pig sectors.

The demand analysis is then generalised to a full simultaneous and recursive model employing the Rational Expectations hypothesis. The implications of the solution procedure are outlined and the results indicate that risk perception associated with store demand in the pigs market and both store supply and demand in the sheep market are important features of trading.

The results of using two different expectations models are then compared. General conclusions are drawn and the overall influence of risk in the store markets is assessed.

PREFACE

The admission of risk into any economic framework implies an acceptance of the maxim that economic theories cannot be reliably conceptualised in deterministic terms. This is almost too self-evident to require stating, yet the development of a rigorous theory of risk has been a long time in gestation and is by no means universally accepted.

Robust theories do exist but there is often a chasm between consistent models of risk behaviour and their application to real-life situations. This is a difficulty which is addressed in this work. A synthesis of the reasons why risk should arise in a dynamic economic market is explored and expectations formation, which plays a crucial role in the evaluation of subjective risk for decision-making purposes, is examined within the context of the store livestock markets in England and Wales.

I am conscious of the enormous debt I owe to a number of people who have assisted, persuaded and taken the time and effort to nurture the economic ideas presented herein. It is not an understatement to say that a research thesis is the combination of the work of many and that the author's main task is to organise the material into some logical form. Anyone who has undertaken such a project will immediately appreciate this.

First and foremost, my thanks are extended to George Jones and George Peters who, as my supervisors at Oxford, have taken decisive roles in establishing much of the content of this work. Other members of the Institute of Agricultural Economics have assisted along the way. Additional thanks are due to George Zanias, Paul Anand, Shirley Brown and Ken Clark. Computational difficulties were immeasurably eased with the help of Paul Griffiths and Glynnis Edwards of the Oxford University Computing Service. My wife, Judith, has provided the moral support which a task of this size inevitably requires. My love and thanks are extended to her. Finally, the work in its entirety is dedicated to the memory of my parents.

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CHAPTER 1

INTRODUCTION

1.1 The Problem

The analysis of risk has become a major preoccupation of agricultural economists. It is a key area of research because its influence is thought to be pervasive. Since the stochastic environment is subject to unforeseen fluctuations in prices and output, for instance, then risk analysis simply investigates how such events influence economic decisions.

The fact which we do not fully understand the economic world is reflected in our inability to exactly predict or control it and the extent of our ignorance is definitionally known as risk. Despite its indeterminate nature, however, a consistent and logical theory can be developed. The purpose of theory is to place risk into perspective of what knowledge we do have against what level of knowledge would be sufficient to fully describe economic systems.

Time is an important adjunct to the study of risk. The future, for example, plays an important role in economics simply because economic activities take time and often decisions have to be made on the basis of what the future is likely to hold. To deny the existence of the influence of time is to largely deny the importance of risk in its most general sense.

The real problem is to utilise what information is available: how it can be processed so as to minimise the adverse effects of risk and how it can help to predict the future.

1.2 The Objectives

The purpose of this thesis is to examine the nature of risk in an agricultural setting and specifically in relation to those forces which have a bearing on the store livestock markets in England and Wales.

The first set of major objectives investigates the effect of risk within the markets chosen and in related influences and activities. Thus, we...

- 1) Identify each potential component of risk in the store livestock markets and define those aspects of the production and marketing processes that make the sector risky.
- 2) Examine the 'grazing problem' for ruminant livestock and show how the existence of risk restricts the full utilisation of grazing resources.
- 3) Define the decision processes in store purchasing and illustrate how and why subjective risk is important for the feeding farmer.
- 4) Investigate a more general supply and demand structure for the industry and show how this vertical structure affects risk perception.

By implication of the decision-theoretic aspect of risk we must examine how the future influences decisions made today: how expectations are formed.

This defines a second pair of objectives:

- 5) Define the expectations mechanisms.
- 6) Establish the relationships between expectations and risk at both an empirical and theoretical level.

1.3 Methodology

An empirical study is undertaken although the results are presented in a manner which devotes as much space to the method, scope and assumptions of the analysis. General assumptions are to be found in Chapter 4 and specific details will be presented in context. They are, in that respect, presented as a 'package' for measurement is meaningless without theory. The approach is pragmatic, or as J. Neville Keynes (1890) said

"all induction is blind, so long as the deduction
of causal connections is left out of account" Pg 164.

1.4 Plan of the Study

Chapter 2 provides the theoretical grounding on which risk and expectations analysis is based. Other theoretical and empirical work is therefore examined and the chapter also provides a general mathematical introduction to risk and expectations theory as a prerequisite to understanding the subsequent chapters.

Chapter 3 examines the biological and economic structures in the store livestock markets for beef, dairy, pigs and sheep and also provides a more general setting from which the components of risk may be identified.

In addition, a section is devoted to the numerous official policies that have had some influence on the store markets in our study period. It is well known that risk perception by farmers may be significantly altered by stabilisation policies of one type or another (Newbery and Stiglitz 1981). This section fully outlines the policy issues involved.

The full theoretical implications of the empirical measures of risk used in this study are outlined in Chapter 4. Our own analytical approach is justified and a general setting for model building is provided.

The first empirical section in Chapter 5 investigates the extent to which the level of risk may be an important phenomenon in a grazing situation.

Grassland production is examined in relation to experimental and actual data. Since grazing is a significant aspect of the cost structure for ruminant livestock in the store industry, then we may examine the effect of risk from the point of view of intensifying grazing utilisation by increased use of fertiliser. A key issue is whether greater grassland output is associated with more risk.

Chapter 6 investigates the role of decision-making in the store livestock sector. A demand structure is posited and Adaptive Expectations are used to define risk. A rigorous account of the mathematical and empirical methods employed is given.

The results are then generalised in Chapter 7 where a full simultaneous model is developed. The vertical structure of store trading relations is examined and store supply and demand decisions are investigated. The Theory of Rational Expectations is used to define risk and the mathematical and empirical methods by which this is done are outlined.

The results are drawn together and compared in the Conclusion which provides a general overview of what has been achieved.

For convenience and to avoid disruption of continuity many of the more technical results encountered in the course of reading this thesis will be found in the appendices. The subject matter of the appendices will satisfy one of two criteria:

- 1) The argument is original but is not necessary for an intuitive understanding of the main hypothesis. For greater rigour, or a further example, the appendix is the appropriate reference.

- 2) The argument is based on another author's detailed result and is more in the nature of an 'aside' that will not leave the main context unduly ambiguous. Obvious results are not given.

1.5 The Structure of Explanation in the Thesis

This thesis is designed to be as self-contained as possible. The reasoning behind the structure of the chapters is that each one builds and develops the ideas of the preceding chapter (except for the introduction!). The discussion of the results in both their theoretical and empirical contexts is therefore complete.

Thus, Chapter 2 serves to introduce Risk and Expectations theory, to show how each is related, and to place each major theoretical contribution to risk theory in context. This simultaneously provides the theoretical results on which this thesis is based.

A mathematical introduction is provided for expectations theory. This is not so important for Adaptive Expectations (although it is not trivial), but is more so for Rational Expectations. Rational Expectations was originally a mathematical device, and many of the difficulties associated with the implementation of Rational Expectations theory at an empirical level are mathematical in nature. It is therefore important to understand the implications of the theoretical results being used.

The markets that form the basis of this thesis are examined next. Their structure is investigated to show why the study is relevant in relation to risk, and to suggest ideas about how store markets should be modelled. It is fairly straightforward although the review of official policy in the livestock markets acts as a precursor to some major conclusions of the effects of risk perception in the store markets.

The fourth chapter illustrates exactly what modelling approach is used and what theoretical assumptions are necessary for the empirical results to have 'theoretical content'. Chapter 4 is a synthesis of the previous two with respect to the methodology subsequently used. Thus Chapters 2, 3 and 4 serve to relate the empirical results to the analytical field in general.

From this point onwards it should be clear how each empirical chapter can be related to the theoretical results and how each empirical result is then a test of economic theory.

The conclusion draws together the work of the empirical chapters 5-7 showing how they have provided tests of economic theory. It will show exactly what contribution this thesis has to make to the body of empirical evidence on the existence and effects of risk.

CHAPTER 2

RISK AND EXPECTATIONS

2.1 Introduction

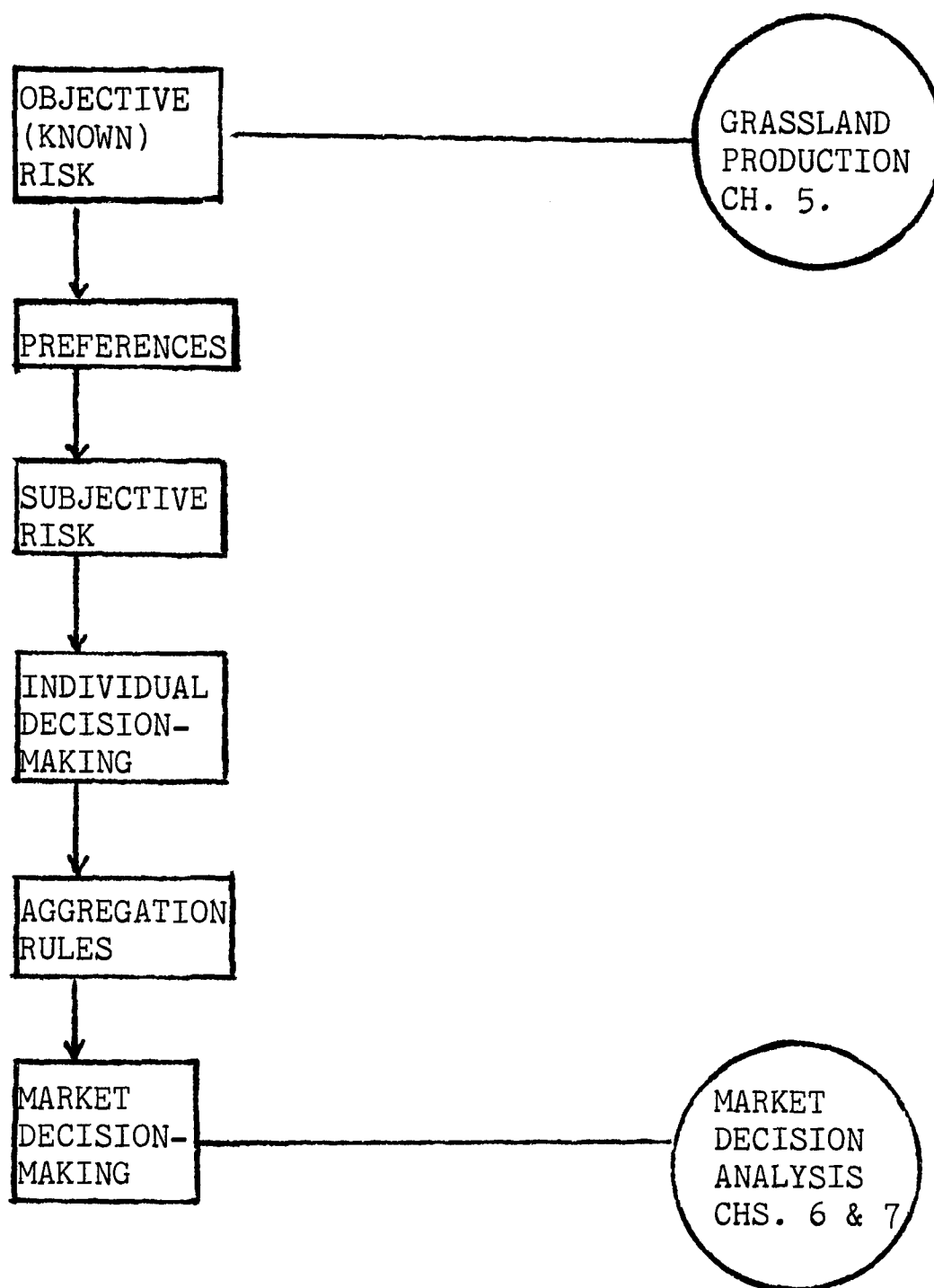
This chapter introduces risk as a theoretical concept and examines the role of expectations theory in the risky decision-making process. Other work is examined and is included to highlight the point of departure from previous studies.

2.2 The Existence of Risk

Risk has been ambiguously defined as some measure of our ignorance of stochastic economic phenomena (Sec. 1.1). It represents the extent to which we accept that we may be mistaken in our decision processes. In other words, what weight can we attach to the 'correctness' of our opinions? Conversely, what then is the weight we can attach to the 'incorrectness' of our opinions and how does this affect decision-making?

Figure 2.1 provides a diagrammatic representation of how components of risk theory are linked together. Predictably the distinctions are not so clear-cut in practice. The arrows indicate the order of succession from one box to the next: that is, known risk will be evaluated on the basis of experience. This information may then be used to form opinions concerning future or unknown risk via the preference framework. Subjective risk is then ordered 'according to taste' or preferences, from which decisions are made at an individual level. Aggregation rules then allow conclusions to be drawn at market level. This will become clear in what follows. The circles indicate at what point analysis in subsequent chapters relates to the discussion in this chapter and may provide a useful back-reference when the empirical results are discussed.

FIGURE 2.1 LOGICAL STRUCTURE OF ELEMENTS OF RISK THEORY



2.2.1 The Evaluation of Risk

We begin by accepting that the concept of risk must be framed in operational terms in order to analyse it. The first task is to show how risk is evaluated or conceptualised in terms of the broadly-based methods available. We also illustrate how risk theory is really a synthesis of a number of academic disciplines and show at what point and to what level competing theories may be judged to contribute to risk analysis in the context of our logical structure (Fig. 2.1).

The Probability Approach to evaluating risk is the most common. It assigns numerical values to the likelihood of a future event occurring which is based on the history of its previous occurrences. Given knowledge of the relative frequencies of past events, perhaps from relevant experience, we extrapolate this information to help predict the future. This assumes the existence of relevant experience and hence exposes the distinction between risk and uncertainty.

Uncertainty appears in situations in which information does not exist about how a view should be formed of an event which has a potential number of outcomes. A probability measure cannot be formed since it relies on historical frequencies. Risky prospects can be evaluated on the basis of probabilities but rely, of course, on previous experience concerning the frequency of events.

Arrow argues that probabilities of unknown complex events can be evaluated from a knowledge of the probabilities of known simpler ones. It is recognised, however, that 'this process cannot go on indefinitely, there must be a beginning somewhere.' (Arrow 1974 pg. 11).

Alternatively, one may use Bayes' Postulate in conjunction with Bayes' Theorem to show that truly uncertain situations - where probabilities are irrelevant - do not arise. Suppose an event B is conditional on any one of the events A_i

occurring. That is, the appearance of any one of the events A_i is a necessary condition for the occurrence of the event B . The conditional probabilities $P(B/A_i)$ and $P(A_i)$ are known. Given that event B has occurred, we ask, what is the probability that it was preceded by the event A_1 (arbitrarily chosen out of A_i) ? Another way of looking at it is that $P(A_i/B)$ is the revised probability assignment to event A_1 after observing event B . The answer is given by Bayes' Theorem, viz.

$$P(A_1/B) = \frac{P(A_1).P(B/A_1)}{\sum P(A_i).P(B/A_i)} \quad (2.1)$$

It was assumed, however, that the conditional probabilities $P(B/A_i)$ and the probabilities $P(A_i)$ were known. This is tantamount to assuming historical frequencies exist and that truly uncertain situations do not arise. In the face of an uncertain situation, Bayes' Postulate suggests the assignment of equal values to all prior probabilities in the absence of any knowledge of their history.

The consistency of the estimate of $P(A_1/B)$ is not affected by this assumption as long as all prior probabilities are given equal value. This is the symmetry condition. To assume, for example, that $P(B/A_1) = 2P(B/A_2)$ is to impose asymmetry into the problem. This must be based on some information about the relationships between the probabilities hence the problem is no longer uncertain (Champernowne 1969 Vol.I Sec. 9.14).

Thus, Arrow's conclusion that uncertainty is not a concept which has any relevance to every-day decision-making is addressed in Bayes' Postulate in a way that even if it did have any relevance it does not affect the evaluation of probabilities and hence risk.

Non-probabilistic methods of evaluating unknown events offer no succinct analytical approach. The 'Degree of Belief Theory' associated with Keynes (1921) and Knight (1921) is an example. The explicit measure of 'Degree' was a probability approach in the sense that it was based on 'some' relation between evidence and the likelihood of an event occurring but it was not necessarily based on measurement. Instead, Knight visualised a system of 'groups' which are derived from a decomposition of the problem into its discernible parts.

A major non-probabilistic approach is Shackle's (1949) Theory of Focus Loss and Surprise. He rejects probability and the Degree of Belief methods on the grounds that the distribution concerning the unknown event can never be verified, even ex post. If an event is unknown, ex ante, then a single realisation, ex post, cannot provide sufficient evidence to enable an agent to form a view concerning its distribution. In fact, an infinite number of observations are required.

Shackle's own analysis rests on what is possible and what is regarded as impossible. He permits a graduation from one case to the other by an assignment of a degree of potential surprise.

In this system there is no Law of Large Numbers or elimination of risk by consolidation of many events. This is because there is no explicit link between the knowledge gained in one situation and another, only a 'development' of experience upon which the economic agent may call to make a judgement. As experience grows the agent may then have a basis for changing his mind about how a future event may turn out (Shackle 1961 Part 4).

The Law of Large Numbers is not applicable because there is no explicit link between knowledge in one situation and another hence there can be no elimination of risk by consolidating information in terms of probability.

But presumably, Shackle does not mean to imply that 'learning' does not exist which is the conclusion we could naturally draw if the Law of Large Numbers is invalid (Arrow 1974). The appropriate conclusion is that probability is an inadequate measure of response to uncertainty in Shackle's scheme. He does allow a range of potential outcomes to affect choice (between, say, 'likely' and 'fairly likely' outcomes) and it is this non-uniqueness of the assignment of risk which invalidates the probability approach (and therefore the Law of Large Numbers).

It will be seen in the next section that the acceptance of the validity of the probability approach does provide a workable hypothesis in which the influence of risk may be examined. Despite Shackle's criticisms of this method it is clear that the denial of the usefulness of probability cannot be sustained when the scale of risk (or uncertainty) is related to ordering rules thereby transforming it into subjective risk. It is the ordering problem to which we now turn and it will be seen that the probability approach can be extended in this framework to provide testable hypotheses which have refutable implications for an aggregated analysis of risk (c.f. Chapter 4), unlike Shackle's which are definitionally individualistic because the underlying measure of uncertainty is ordinally-based.

2.2.2 Subjective Risk

Once risk has been evaluated for each potential outcome of an unknown event then we must define some process by which the results may be ordered according to individual preferences.

Expected utility maximising principles are the most widely advocated methods of appraising unknown events (Dillon 1971). The level of abstraction varies from global utility functions which are normally composed of a single argument (e.g. profits, income, leisure, etc.) to sub-optimal rules defined for specific situations. The latter form preference orderings over the components

of a wider utility function. The necessary assumption is that the individual can relate the component parts to the whole. This is a simple matter given a Utilitarian framework, but is more difficult on a realistic basis where the horizontal structure between each sub-optimal preference ordering and vertical relations to the ultimate goal may not be so easily discernible.

The Expected Utility Theorem provides a numerical measure to preferences.

Von Neumann and Morgenstern (1947) developed Ramsay's (1931) work to rigorously prove that unique values exist for ranking unknown utility based within a probability framework.

The major shortcoming of this approach is that it does not allow any role for decision-costs. They are not accounted for, *ex ante*, but they will constrain decision-making, *ex post*, for decision-costs cannot be avoided.

Alternative methods of ordering risk exist. They are more practically orientated relating observable phenomena to real situations. Probability measures are used in conjunction with other criteria which are examined below. They are basically variations on a similar theme of operationalising risk analysis at the individual level.

The pure Safety Principle is based on the hypothesis that security varies inversely with risk. The underlying assumption is that some basic requirements to sustain economic and physical existence must be satisfied. These aspects of decision-making take priority above all other criteria. It should be noted at this point that pure Safety Rules may be regarded as special cases of the Expected Utility Hypothesis where an income level, for example, which falls below subsistence requirements has zero weight in the utility function and income above the subsistence level has a weight of unity.

The Safety First Principle (Roy 1952) minimises the probability, α , that some objective function (typically profits, π) falls below a pre-specified 'disaster' level, $\bar{d}$; that is

$$\min \alpha = P(\pi < \bar{d}) \quad (2.2)$$

Chance-constrained programming (Charnes & Cooper 1959,1963) alternatively defines the Safety Principle as a probability limit beyond which the disaster level is defined; viz.

$$\min P(\pi < \bar{d}) \leq \bar{\alpha} \quad (2.3)$$

An alternative is Kataoka's Rule (1963) which maximises the minimum return which can be achieved with a fixed confidence level (Safety Fixed Rule) equal to

$$\max(\min) P(\pi < d) \leq \bar{\alpha} \quad (2.4)$$

Safety Principles are based on the exclusivity of the safety requirement: that is, no consideration is given to other objectives before the safety criterion is met. Because it is aimed at practical situations this assumption may not be very satisfactory when a number of criteria enter the decision-making process. Lexicographic methods are able to deal with multiple-goal situations. However, this is done in a fashion which assumes fixed relations between different objectives that are vertically structured. That is, the agent satisfies the most urgent objective before any other is considered. The difficulty with fixed vertical relations is that the fundamental nature of the problem may alter when certain criteria are met. There is only limited scope for this type of change in the lexicographic approach. Thus Lexicographic Safety First Rules require the maximisation of the expected value of profit, say, whenever the chance constraint is met,

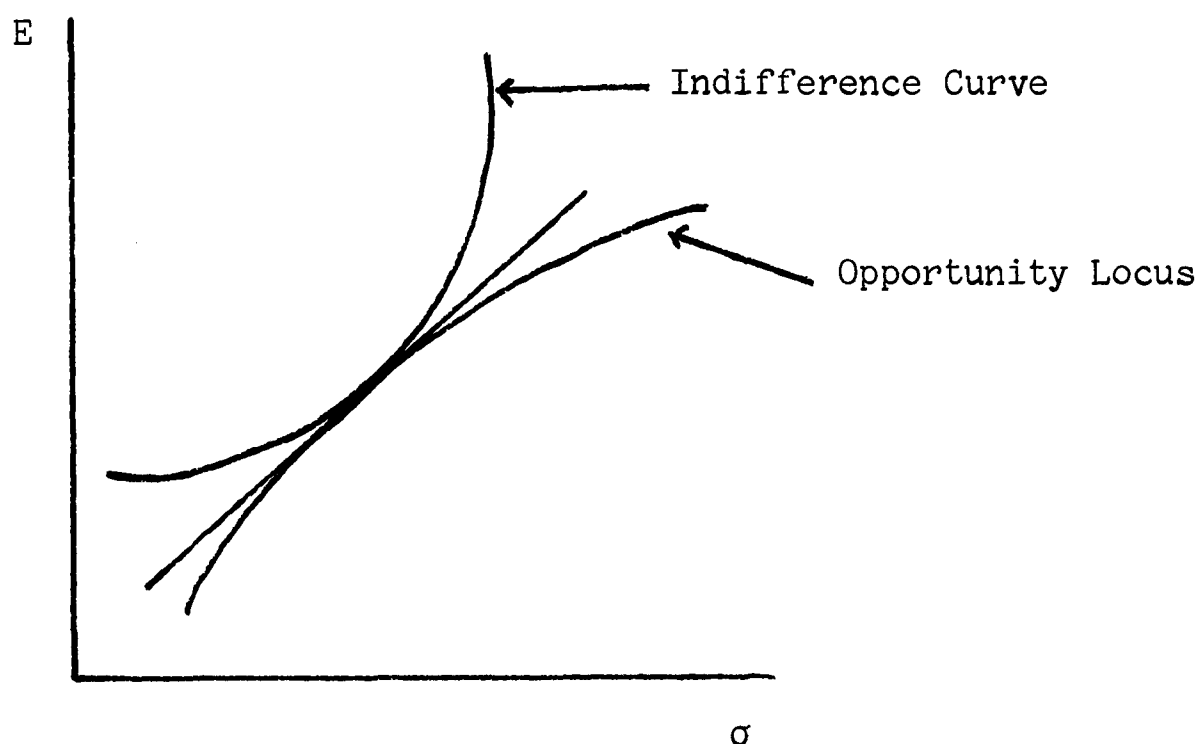
and minimise the probability of disaster when it is not. Lexicographic Safety Fixed Rules involve maximisation when chance constraints are met and following Kataoka's Rule when they are not. The scope for limited change exists if we define 'disaster' or 'profit' widely enough so that 'disaster' definitionally encompasses its components which may alter without changing the objective of minimising disaster (or maximising profit).

At a more esoteric level, Shackle's criteria for measuring uncertain situations by focus loss and gain can be translated into a decision-making process by adding to the scheme individual preference functions from which the appropriate tangency conditions may be observed. They are not preference functions in the sense that we have already described them but rather they represent how an individual's cognitive process responds to the surprise function and the possibility of loss or gain in the uncertain situation. Shackle's primary motivation in developing his theory was to simplify choice in uncertain situations so that decision-criteria could be realistically evaluated. That is, instead of using probability calculus - which he adds that most people would not understand - he specifies maximum surprise, minimum surprise and the space in-between. Shackle's theories are then developed in this framework. Although they are clearly case-specific, and hence no general conclusions may be drawn (Roumasset 1976), they broadly represent a decision process which is closer to actual decision-making. For instance, to evaluate probabilities to define risk requires the attachment of specific numbers to uncertainty which many people, Shackle argues, are unwilling or unable to do. If, on the other hand, we define 'regions' of risk or uncertainty which enter as decision-criteria then decision-making relates more closely to the actual environment. Any criteria entering regions of 'surprise space' can be assessed as either 'too risky' on which to base a strategy or 'insufficiently risky' so as to deter the implementation of the strategy (Shackle 1961).

When the form of the preference function is unknown optimal strategies can no longer be defined. Instead efficient decisions are contemplated. Stochastic Dominance Theory is the main analytical method which tackles this problem and is based on the assumption of prior knowledge of the distribution function of risky prospects and a positive preference for greater wealth or more utility ($U' > 0$). The idea is to derive unanimous or partial preference orderings over pre-specified risky situations. This is achieved on the basis of rules defined in terms of orderings of cumulative distribution functions. In this way, a decision is efficient if its ongoing or cumulated risk, specified in terms of the parameters of its distribution, is less than an alternative decision strategy. First Degree Stochastic Dominance of one set of outcomes against another is guaranteed if one cumulative probability is everywhere greater - that is, more certain - than the other. It is then seen why $U' > 0$ must be assumed because if $U' > 0$ held in some regions and $U' < 0$ in others then cumulative probabilities may add up to zero.

Mean-Variance analysis also satisfies the efficiency criterion although this can be specifically derived from a utility framework (see Sec. 4.2). Combinations of different means and variances are plotted (in E-V space: mean-variance) and compared with an individual's indifference curve. The indifference curve is defined by levels of constant expected utility. For a risk-averse individual, increases in variance must be associated with greater mean returns to maintain utility assuming variance to be a specific measure of risk. The different combinations of decisions to be made are reflected in the opportunity locus. For a decision between two crops, the opportunity locus will be convex to the origin (as shown) if any combination of either is less risky than relying on only one crop.

FIGURE 2.2 MEAN-VARIANCE SPACE AND THE TANGENCY CONDITION



Within this framework, other approaches assume different parameters to be important. The Mean Absolute Deviation Approach popularised by Hazell (1971) and the semi-variance method of Markowitz (1970) are examples where different features of the relevant distributions are emphasised.

More ad hoc methods of ordering risk exist which defy strict classification. One approach is based on satisficing some preference which relates to specific situations. The concept of satiation plays no role in Classical Economic Theory whilst it has entered prominently into the treatment of motivation in psychology. In most psychological theories, according to Simon (1959), the motive to act stems from drives and action terminates when the drive is satisfied. Moreover, the conditions for satisfying the drives are not necessarily fixed. They may be specified by an aspiration level that itself adjusts upward or downward on the basis of experience.

How far the approaches reviewed differ from one another can be debated. Satisficing, for instance, does explain interim movements to equilibrium more than a general maximising principle would because it can be related to a specific situation where decisions are continuously adjusted as information is obtained; but then again, there is no adequate theory to

extend to the general case. Binswanger (1979) suggests that alternative methods of ordering uncertain prospects are essentially the same and have been observed yielding similar results in empirical investigations. Which method one uses will be defined by the level of theoretical rigour required.

2.3 Empirical Risk Measurement

Applications of risk analysis have broadly followed the theoretical results that have been reviewed. The significant feature to appreciate is that most results support the existence of the influence of risk (aversity or preference) although it is more difficult to find support for the approach used.

The Direct Utility method of empirical risk measurement is based on von Neumann & Morgenstern(1947) axioms and has been extensively employed by behavioural psychologists. This consists of confronting the subject with choices between risky and riskless prospects, or between different risky alternatives and estimating utility functions from which their risk preference characteristics may be examined. Dillon & Scandizzo (1978) have used this method in N.E. Brazil. Lin, Dean & Moore (1974) used data from (relatively) wealthy Californian farmers. Their results provided positive evidence for the existence of aversity to risk over different sections of different utility functions.

Roumasset (1976) found contrary evidence. He examined the reasons why fertiliser applications fall-short of profit-maximising levels with respect to rice production in the Philippines. The presumption was that risk aversity inhibited fertilisation. The motivation for investment in fertiliser would be the expectation of a higher mean return in output. However, if the higher mean return had associated with it a proportionately greater perceived risk then risk-averse producers would not adopt such a strategy. For a given level of income a higher proportion invested could possibly lead to financial

ruin. How this possibility would arise was examined by Roumasset. He developed an approach of combining personal probabilities of particular risks or 'disasters' with an experimentally derived production function of fertiliser on rice output. 'Disasters' were measured in terms of Risk Sensitivity Indices which represent elicited opinions on how Philipino rice farmers viewed the potential devastation to their crops by a typhoon or a major pest outbreak. Investing a higher proportion of a given income would increase the degree of exposure to such risks in terms of financial ruin. The evidence suggested that farmers cannot be averse to increasing investment on account of risk because Roumasset found that higher fertiliser applications do not substantially increase financial risk. Therefore, risk aversion cannot be a primary cause of fertiliser applications falling short of profit-maximising levels; rather, farmers may not have used fertilisers because the finance, by which increased output could be achieved, was not available.

The main difficulty with this and other approaches which rely on utility or preference elicitation is that the situations that people are asked to judge are hypothetical. There is little to lose in making a choice. Decision criteria are quite divorced from those found in actual agricultural situations. This view is supported by Binswanger (1978) from his work in rural India. He came to the conclusion that results on risk preferences from interviews are 'unreliable, non-replicable and misleading.' It is difficult to believe that valid conclusions may be inferred from elicitation methods to situations involving actual choice. There can be no guarantee that risk preferences elicited in this manner are relevant to anything other than the question and answer session from which they were derived.

The second main empirical approach to investigating risk is by the econometric method. If the econometric results at market level are derived from microeconomic risk theory then these methods implicitly assume that aggregation rules are satisfied. We investigate this in more detail in Sec. 4.3.2 but shall assume, for the time being, that they do not affect the evidence to be reviewed.

Carlson (1979) studied pest control in Nicaragua and other Central American countries where he analysed the effect of an expanded pest management scheme on cotton acreage from 1964-1974. Response to the introduction of the scheme was taken as a proxy that farmers viewed pest control as a major priority of production. The effect of the scheme was measured as a zero-one dummy variable and the results showed that the scheme had a significant influence on the subsequent expansion of cotton acreage.

Behrman (1968) studied rice supply in Thailand covering 30 provinces between 1940-1963. In estimating response elasticities he devised three surrogate measures of risk aversion:

- 1) The standard deviation of price over the 3 preceding years.
- 2) The standard deviation of yield over the 3 preceding years.
- 3) The population residing in agricultural households in relation to agricultural output.

For both measures 1) and 2) significantly negative responses were obtained in slightly less than half the provinces. The third measure was taken to be a reflection of possible peasant behaviour in planting enough acreage of rice to produce sufficient food to feed the population. That is, it was a population/food 'survival' variable.

Significantly positive responses to this were found in 70% of the cases. This indicated that minimal subsistence requirements are important in the decision-making processes of Thai rice farmers providing tacit support for the safety approaches mentioned earlier.

Risk measurement based on an expectations mechanism to approximate aggregate decision-making is rather more popular. If we use the standard deviation measure to illustrate our discussion then we see that risk may be viewed in two ways.

Firstly, we could suppose risk to be based on variations about an average or normal value of the 'risky' variable: that is

$$\text{STANDARD DEVIATION} = E\{ \sqrt{(X - \bar{X})^2} \}$$

This would provide a measure of 'stationary' risk because it is based on a single-valued average which is assumed to hold for all time. It is quite an unrealistic measure, of course, during times of dramatic change when the true value of $\bar{X}$ may significantly alter and even though the stationary measures still represent deviation it no longer represents a reasonable view of risk since people will have revised their estimates of the average or norm. Alternatively, by definition, averages or mean values mask variation which may be a significant component of the deviation measure of risk. To account for this a 'moving' risk measure is posited:

$$E\{ \sqrt{(X - E(X))^2} \}$$

where $E(X)$ is not to be taken as the simple average just discussed. $E(X)$ is not single-valued for all time but will change according to an expectations mechanism as new data and information arises. In this way dramatic changes are accounted for, and therefore, 'moving' risk is a more realistic measure. Risk 'moves' according to an expectations hypothesis which then defines $E(X)$. It is a major aspect of this thesis to investigate what implications different expectations hypotheses have for risk-perception in the store markets.

Just (1974) employed the Adaptive Expectations rule to define $E(X)$ but, in his example, he used variance instead of the standard deviation; that is:

$$E\{ (X - E(X))^2 \}$$

Just's results are by far the most successful in terms of statistical significance. He found both risk-prone and risk-averse response to variations in prices and yields of certain crops grown in California. The degree of variation was limited, however, by Government control with respect to marketing quota arrangements, price supports and crop diversification policies. Just came to the conclusion that response to risk would be 'muted' by these policies since the correlation between statistically poor estimates of risk response and Government intervention was high. Thus, the result is that much of the scope for exhibiting risk response (prone or averse) would be reduced.

Prosser (1980) adopted a similar approach in analysing risk response in Australian wheat production but found risk to be unimportant. Similarly, Traill (1978) concluded that price risk was unimportant in explaining U.S. onion acreage where his measure of risk was based on a standard deviation of prices. But Traill's detailed iterative estimation technique failed to produce any conclusive results even though the estimated coefficients were only marginally insignificant.

2.4 The Importance of Expectations

We have already discussed the concept of 'moving risk' which is partly defined by an expectations mechanism. The role of expectations in the evaluation of risk then immediately suggests an appropriate motivation for studying the effect of risk in any particular market. That is, if a market exists in which its dynamic structure is an important part then expectations are likely to play a role in decision-making. Farmers, however, may not be so sure about their estimates of expectations hence they may allow a role in their decision-making processes for the risk of misestimating expectations. This section investigates dynamic markets and the role of expectations whilst it will be left to Chapter 3 to show exactly what dynamic structure occurs in the store markets.

Since in this thesis the store markets in England & Wales are studied we approach the investigation from a fairly aggregated level. Chapter 3 outlines the economic and biological relations in each store market where it will be seen that because of the time involved in the production process resources have to be committed before the returns to production are known with certainty. A decision on what level of resources to commit must therefore be based on expectations about what the future is likely to hold in terms of revenue and since the future is uncertain then risk arises as a potential influence. Alternatively, risk is a feature of the Store Markets because production is based on what the future is likely to be, and if farmers are wrong in their view of this then they will commit the wrong level or mix of resources and hence lose money in the process.

Underlying this point of view is the Cobweb Theorem (Ezekiel 1938) which has latterly been used in the more general context of dynamic response (Nerlove 1972). Farmers must make decisions on an ex ante basis because of the dynamic structure of market relations which are, in turn, determined by the biological production relationships. Ex post realisations of revenue will only be equal to ex ante views by coincidence. In a working environment a conscious effort has then to be made in order to guess at what state the market will be when a particular farmer's produce reaches a sale-point. This will force the farmer to consider alternative production strategies because to establish the superiority of one strategy over another at least one comparison must be made. Since the consequences of various strategies are unknown, ex ante, risk and expectations enter the decision-making process. The better informed are farmers' views of the future the less likely are they to be subject to misestimation and hence subject to the influence of risk, for risk is defined as the variance of misestimated expectations.

The definition of subjective risk that is used throughout this study, which relates to the variance of misestimation, is:

$$E[(X-E(X))^2] \tag{2.5}$$

$E(X)$ is defined by some expectations process and is not to be taken simply as an estimate of a constant mean value as we have previously mentioned in relation to 'moving risk'. We use the definition of risk as shown in equation 2.5 which is the most general form of the definition of the variance of any variable (Koutsoyiannis 1977 pg. 534) and it is therefore left to us to specify exactly how $E(X)$ is defined. We define $E(X)$ by an expectations mechanism and employ a model of 'moving risk'. It should now be clear, subject to aggregation rules, why the examination of expectations theory is important to the analysis of risk. The justification for the variance measure of risk will be found in Chapter 4.

2.4.1 The Meaning of Mathematical Expectation

Expectations are required when a distinction exists between the information available and the information required in order to decide upon a course of action. This distinction is based on time. If farmers wish, for example, to decide on a level of production then they must do so on the basis of what they expect the likely demand to be in the market at the time when the goods become available for sale. This point is most easily established in an agricultural framework where a production period can be realistically set at twelve months, for example. A farmer has to decide on the basis of information currently available what mix of crops will bring the greatest returns at harvest in a year's time. He has to form an expectation of the likely future demand for all the crops that he cultivates because information about demand patterns is not currently available. If he had knowledge of demand then there would be no point in forming expectations. Since this information is lacking then he will form his expectation in the current period for the

likely pattern of demand to occur next period (that is, when his crop is sold). Algebraically, it is a mathematical expectation conditional on information currently available. If the production period can be defined as the difference in time of t and $t-1$ then conditional mathematical expectation may be written as

$$E(X_t/I_{t-1}) \quad (2.6)$$

where X_t is the pattern of demand in time t and we have information, I_{t-1} , currently available up until the end of period $t-1$. Expectation is intuitively a time-difference relationship and therefore holds for all time; that is:

$$E(X_{t-i}/I_{t-i-1}) \quad (2.7)$$

We can therefore arbitrarily define our 'base period expectation', or exactly what time period we choose to define when information is 'currently available'. Hence the reasoning given for the expression 2.6 can be equivalently set in terms of current information available up until time t and we form our expectation for time $t+1$. It is clearly up to us to define our 'base-period' expectation conditional on available information. We shall employ this particular device in Chapters 6 and 7 where the economic meaning, as opposed to mathematical (the 'time-difference' relationship), aspects are discussed.

2.4.2 Some Features of Adaptive Expectations

This section is the first of two that examines the expectations hypotheses that we shall subsequently use in our analysis of risk. We have seen that expectations are required if 'moving risk' is to be used in equation 2.5 and that we will have a valid measure of risk in the market which may be derived on the basis of individual utility theory should

aggregation rules hold (Secs. 4.2.1 and 4.3.2). Sections 2.4.2 and 2.4.3 reveal exactly what is involved concerning expectations although their precise consequences for the evaluation of risk will be left until the results are presented in the empirical chapters.

Adaptive Expectations (AE) are the first of two expectations hypotheses to be examined. The hypothesis is defined (after Cagan 1956) as:

$$P_t^* = P_{t-1}^* + \gamma (P_{t-1} - P_{t-1}^*) \quad (2.8)$$

which states that this period's expected price is assumed to be related to last period's expected price plus some adjustment for the misestimation of expectations from actual price in the previous period. Information is assumed to be available up until I_{t-1} . The rate at which the error-learning process proceeds is judged by the adjustment coefficient, γ ($0 < \gamma < 1$). The equation 2.8 can be rewritten

$$P_t^* = P_{t-1} + (1 - \gamma) P_{t-1}^* \quad (2.9)$$

By continuous back-substitution in equation 2.8 further insight into the hypothesis is gained by showing that

$$P_t^* = \gamma \sum_{i=1}^{\infty} (1 - \gamma)^{i-1} P_{t-i} + (1 - \gamma) P_{t-1}^* \quad (2.10)$$

Equation 2.10 illustrates that the error-learning or behavioural rule 2.8 is really an assertion that current expectations are based on an extrapolation of weighted averages of past actual prices. But, mathematically, this is no different from purely extrapolative systems. Over fifty years ago, Fisher (1930) suggested that individuals might forecast future inflation rates as a weighted average or distributed lag of actual past inflation rates.

What would make the AE hypothesis different from the purely extrapolative systems would be theoretical content. This has been discussed by a number of writers (Griliches 1967, Nerlove 1972) who draw the conclusion that AE cannot be an explanation of expected prices. It is because AE can be represented as a weighted time series of its own actual values that makes it observationally equivalent to any number of theories. What remains unexplained are the economic forces which determine prices from one year to the next. To say that AE is related to past actual prices is begging the question as to what influences prices?

Econometric applications of the hypothesis (Jones 1961) attempt to infer economic content on an argument-by-example basis. The approach is to estimate adjustment coefficients and relate the results to the markets under consideration.

A simple example will illustrate how this is done. Consider the model

$$Y_t = \alpha P_t^* + \beta Z_t \quad (2.11)$$

$$P_t^* - P_{t-1}^* = \gamma (P_{t-1} - P_{t-1}^*) \quad (2.12)$$

which could represent supply response of output, Y_t , to expected price, P_t^* , and some exogenous influence, Z_t . Lagging equation 2.11 and subtracting from the same gives:-

$$Y_t - Y_{t-1} = \alpha (P_t^* - P_{t-1}^*) + \beta (Z_t - Z_{t-1})$$

substituting in equation 2.12

$$Y_t - Y_{t-1} = \alpha \gamma (P_{t-1} - P_{t-1}^*) + \beta (Z_t - Z_{t-1})$$

From equation 2.11

$$\gamma \alpha P_{t-1}^* = \gamma (Y_{t-1} - \beta Z_{t-1})$$

Hence

$$Y_t - Y_{t-1} = \alpha\gamma P_{t-1} - \gamma(Y_{t-1} - \beta Z_{t-1}) + \beta(Z_t - Z_{t-1})$$

or

$$Y_t = \alpha\gamma P_{t-1} + (1 - \gamma)Y_{t-1} + \beta Z_t - \beta(1 - \gamma)Z_{t-1} \quad (2.13)$$

Ordinary Least Squares estimation of this equation would provide an estimate of (1-gamma) from which alpha and the whole equation is statistically identified.

This particular method rests on the lagged dependent variable defining (via its coefficient) the AE adjustment mechanism. If there are other reasons why a lagged dependent variable should be included in the equation 2.13 (because of delayed quantity response for instance) then a problem of indeterminacy arises. Estimated parameters can only be identified in an economic sense given that a unique meaning can be attached to gamma although equation 2.13 has long-run consequences irrespective of gamma should the lag structure be removed (mathematically, the 'equilibrium' solution of any difference equation). In the long run, of course, gamma = 1 which, on substituting this value into equation 2.13, produces equation 2.11 but with the actual value of price substituting its expected value. If economic meaning can be attached to gamma then gamma describes the adjustment mechanism which is in accordance with the theoretical structure defined in equation 2.8. This does not, in itself, imply that the AE hypothesis has theoretical content. However, if the resulting estimates in equation 2.13 are superior to competing mechanisms then some justification for using the rule can be claimed. The whole question of theoretical content in this respect rests on the validity of the original structure (equation 2.8) and whether or not the AE hypothesis can support this via statistically significant results in equation 2.13.

As an alternative, theoretical content may be inferred from within the context of a more general optimising principle. Muth (1960) has shown that for certain non-stationary time series AE provides an optimal forecasting mechanism. Such a principle, therefore, is then easily incorporated into any maximising framework.

2.4.3 Some Features of Rational Expectations

In this section we will provide a detailed discussion of some very recent developments in Rational Expectations (RE) theory. It is important that they should be introduced at this stage because many of the implications of the results will be subsequently used. Thus we examine the structure of error generation in RE models, stability properties, information requirements and illustrate the discussion with an example.

The Theory of Rational Expectations (Muth 1961) sets out to fully develop a reasoning on how and why expectations are formed in the manner they are. It can define a unique mechanism for each situation, but remains a general theory. The distinguishing feature is that it is a theory which can be subject to empirical testing unlike AE which faces an economic interpretation problem.

Rational Expectations are defined as "true mathematical expectations of future variables conditional on all variables which are known to the public". Shiller (1978 pg 3). That is, the mathematical expectation incorporates not only the quantity of information but also how the information is pieced-together. It is this latter aspect which provides the theoretical content of RE.

Exactly how one piece of information is related to another is normally conceptualised in terms of an economic model. This provides the testable part of the RE hypothesis. For expectations to be Rational they must therefore be consistent with the proposed structure of the model which in turn is meant to reflect reality. In other words, Rational Expectations are meant to represent the true expectations of the economy or market. In this sense, RE are endogenous expectations: they are explained within the structure of the market place.

RE is a forward-looking mechanism. It does not rely on past information to get it to a position or solution where expectations are Rational but uses past information to direct where the model explaining the market structure should be leading. Economic models incorporate new information simply as an increase in the available data (cross-section or time-series). They do not explain how information is assimilated as part of a cognitive process. This is a criticism of economic models in general and not of RE models in particular. They approximate this situation as partial or full availability of new information but do not explicitly state how this information is understood. This new information may certainly be absorbed by economic agents but this does not necessarily imply understanding.

In RE models the incorporation of new information is assumed to have a one-off effect. It is immediately absorbed (though not necessarily correctly) and does not have a lingering effect as would be the case in the error-learning mechanism of AE. New information in an AE framework is geometrically weighted over production periods. Complete adjustment will only occur after a considerable amount of time has elapsed (for γ not equal to 1). In a Rational environment, people are assumed to be more concerned with what is going to happen than with what has already happened. They look for a path to equilibrium and RE illustrates how this is achieved (or at least one consistent method of achieving equilibrium). If new information becomes

available which suggests that the market under consideration will come to rest at a different equilibrium to what was previously thought it is Rational to then make decisions on the basis of the new situation. To only gradually adjust to such a situation - as would be the case under AE - would be irrational. If such a course was followed people will consistently make mistakes because their decisions concerning production, say, are not fully adjusted to the new information. This is not the same as saying that production has to be adjusted immediately but that the complete information set which determines such decisions is not being fully utilised. Those people who fully incorporate the new information will be well placed to make non-normal profits.

This would be the Rational thing to do, but does not deny the existence of the possibility that people may make errors in their expectations formation. The errors may occur as a result of the way in which information is processed. In this case errors may arise because people may have not fully understood the ramifications of the new information. Systematic errors cannot therefore be made once the 'true' structure of the model is known. Information will always be absorbed once it becomes available, but how it is used is subject to how true a representation the model from which expectations are made is to reality.

Because RE is forward-looking, and because it incorporates all the information currently available, there is no reason to expect forecasting errors from a RE model to be anything but random. Systematic errors would arise as a result of people's failure to understand the economic system in which they operate. But if forecast errors were expected to be biased, then people might as well incorporate this information in their view of expectations.

However, as Shiller (1978) points out, forecast errors are serially uncorrelated but not necessarily serially independent. This relates specifically to forecasts which are required for more than one period ahead, viz. P_{t+1}^* / I_{t-1} . Without loss of generality, suppose current information is available up until the end of the period $t-1$ so that a one-period expectation is P_t^* / I_{t-1} and a two-period expectation is P_{t+1}^* / I_{t-1} . A forecast error is then defined as:

$$\epsilon_t = (P_t - E(P_t / I_{t-1})) \quad (2.14)$$

but for a two-period forecast

$$\epsilon_{t+1} = (P_{t+1} - E(P_{t+1} / I_{t-1}))$$

is made on the information currently available at time $t-1$.

Begg (1982) decomposes the forecast error into two parts relating to each time-period

$$\epsilon_{t+1} = \eta_t + \eta_{t+1}$$

Now, η_t is equivalent to the forecast error ϵ_t defined in equation 2.14, but η_{t+1} is that forecast error which occurs on the basis of new information available at time I_t , viz.

$$\eta_{t+1} = (P_{t+1} - E(P_{t+1} / I_t))$$

It is the incremental error as new information arises. Thus, ϵ_{t+1} is the total forecast error and η_{t+1} is the error that may arise when new information at time t becomes available.

By analogy, the two period forecast error for P_{t+2}^* is given by

$$\epsilon_{t+2} = \eta_{t+2} + \eta_{t+1}$$

and clearly

$$\epsilon_{t+2} = \epsilon_{t+1} + \eta_{t+2} - \eta_t \quad (2.15)$$

which exactly shows its serial dependence. This is known as 'overlapping.' It only arises because of the forward-looking nature of RE. This then gives rise to the possibility of Cobweb phenomena because even though expectations may be consistent, errors may be an important feature of the model should expectations extend beyond one period. Compare this with a Cobweb cycle resulting from an AE hypothesis where errors are made because information is not fully utilised (the 'error-learning' mechanism is only gradually adjusted, for gamma not equal to one).

Forward-looking expectations also entails some convergency and stability implications for the dynamics of Cobweb systems it purports to explain. If a convergent path to equilibrium exists then RE will find it. Uniqueness problems arise, however, when more than one path to equilibrium exists, as would occur in a globally stable environment because any path chosen will lead to equilibrium. This is not a problem for AE since it never sets out to test a theory anyway and hence uniqueness can have no implications for the hypothesis. But it is a problem for RE when multiple dynamic solutions occur. Because a RE solution is based on how equilibrium is achieved, and because equilibrium conditions play an important part in the solution to a RE model, then it is essential to be able to identify the dynamic conditions which lead to equilibrium as those which would be equivalently defined by a RE solution.

Since there are two general methods by which RE systems can be solved there are two ways in which the uniqueness problem may be overcome.

The first solution method involves the standard algebraic approach where reduced forms of simultaneous systems are used and where identification conditions play an important role. The 'algebraic' solution can be framed in a variety of ways: the substitution method (e.g. Sargent & Wallace 1975, Wallis 1980) and shown below; the method of undetermined coefficients (e.g. Muth 1961, Taylor 1977) and a method by which a solution is 'guessed' and then tested to see whether the RE conditions are satisfied (e.g. Lucas 1971, Barro 1976). The common denominator is that expressions defining 'RE constraints' are derived which must be satisfied to verify a solution.

The second solution method is the iterative numerical approach whereby systems of equations (invariably nonlinear) are solved by standard numerical techniques (Gauss-Seidel, Newton-Raphson, Gradient, Davis-Fletcher-Powell, etc.) and the solved values of the model used to generate Rational Expectations.

The iterative techniques are augmented by an outer loop to the routines mentioned by which the expectations entering the model are adjusted so as to converge on the model solution. When a suitable convergence criterion is satisfied then a RE solution is found. With respect to the uniqueness problem only the first method is discussed at this stage. Details on the second method will be found in Chapter 7.

The uniqueness problem is approached in an algebraic framework by specifying additional constraints over and above those defined by the RE solution. The problem then turns to justifying the additional constraints. Taylor (1977) has investigated this and has shown that in a globally stable economy where expectations enter as explanatory variables that stability implies a finite variance for expectations. From this observation he suggests that a minimum variance condition on expectations will isolate the RE path to equilibrium. This was justified on the grounds of 'collective rationality' where the costs of making mistakes about expectations are kept to a minimum. Collective rationality is not such an unreasonable assumption given the potential use

of leading indicators such as Government forecasts which are widely available.

This constraint becomes redundant in a saddle-point economy where only one path to equilibrium exists (Chiang 1974). A RE solution is characterised by such an equilibrium condition. To find a solution in a saddle-point economy implies uniqueness. AE cannot claim this property for it is an error-learning mechanism where mistakes are only adjusted to gradually. Any point off the unique path in a saddle-point economy is unstable. To start from a position off the unique path in an AE framework will not lead to an equilibrium solution as it will only compound the errors already made. This is because it is backward-looking, or a geometrically weighted sum of its past actual values. Only if it starts from a position on the path to equilibrium will a convergent AE solution be found. If a RE solution can be found then convergency is assured in a saddle-point economy. Under AE, a stable solution may or may not exist: it is impossible to say.

Globally unstable solutions are empirically unimportant. If expectations are finite today then they are likely to be finite tomorrow. Some would argue, however, that many markets are globally unstable and that only floors and ceilings to production, for example, stop them from collapsing. So-called speculative bubbles do arise but if it is perceived by people that the market will explode then it will no longer be rational to follow such a path. Globally unstable situations are not the norm hence people would have little reason to follow such a path, especially if it leads to market collapse. Brock (1974) and Lucas (1975) argue that this view is theoretically valid within the context of a rational and optimising framework. Minford (1978 a) suggests that it is an integral part of RE theory that people rule out the possibility of speculative bubbles on the basis that they are not a general feature of the economy.

Because non-convergent paths are ruled out a priori, it would appear that RE are self-fulfilling and that tests of the hypothesis are redundant. If the 'correct' answer exists, then it is the answer that a RE solution will choose. It is in this respect 'forced' to equilibrium. Can a RE solution really be justified on the grounds of its equilibrium properties? It may be argued that in the long run the difference between one expectations hypothesis and the next is unimportant.

The distinction to note is that it is not necessary that a long-run or full equilibrium solution exist before a RE solution is found. All that is required is that the expectations are consistent with the underlying model of the market or economy. For example, in full equilibrium, there is simultaneous adjustment to any extraneous influence which does not, in itself, alter the structure of the model hence no recursive relations are required. RE can be quite consistent with a dynamic market and therefore is not necessarily in a long-run equilibrium. What is really meant by a RE equilibrium is that expectations mirror how the model would solve for such expectations. Given that the model is a true representation of the economy, then the expectations so generated are consistent with what is happening in reality.

This is a difficult enough task by itself but would seem impossible in a more realistic environment where information is scarce, variable and sometimes unreliable. In a changing environment, new information would constantly be required to form consistent expectations as people search for the required model. But there are costs to the collection of information as Fiege and Pierce (1976) have noted even if the accuracy and reliability of information is sufficient to render forecast errors random which Friedman (1979) suggests is unlikely.

Others (Begg 1982) have argued that this view is addressing the wrong problem. All that is required is that people act 'as if' they know the true structure

of the model. Even this argument is juxtaposed to the view that economic models which form RE are not complicated enough! It is only because economic models have to be internally consistent and represent aggregated response that makes them complicated. To make them more realistic, for instance, they could be disaggregated to the individual. At the risk of stating the obvious, day to day economic decisions are simpler; they are not generally couched in terms of difference equations satisfying saddlepoint stability properties, but the economic processes which describe such actions are complicated only because of the way economic and logical syllogisms are structured.

This raises the question as to the validity of RE solutions in relation to the model. RE is based on an economic model. If the model is incorrectly formulated then so will the expressions representing RE. It is therefore clear that a test of RE is really a dual (and indistinguishable?) hypothesis: one concerning the inherent validity of the structure of the model; and another about RE theory. RE theory is a combination of the structural parameters of a model which illustrates why RE is dependent on the validity of the model. This is seen from a simple example.

Equation 2.11 is used again but expectations are now set to a two-period forecast to reveal some of the properties of a RE solution. A simultaneous deterministic response is added - with no aspirations to reality - to complete the system. The model is only illustrative to reveal how algebraic RE solutions are derived: the variable and lag structure is chosen primarily for ease of manipulation.

$$Y_t = \alpha P_{t+1}^* + \beta Z_t \quad (2.16)$$

$$P_t = \delta Y_t \quad (2.17)$$

Substituting in

$$P_t = \pi_1 P_{t+1}^* + \pi_2 Z_t ; \quad \pi_1 = \alpha\delta \quad \pi_2 = \delta\beta$$

Taking mathematical expectation on information available at time $t-1$:

$$P_t^* = \pi_1 P_{t+1}^* + \pi_2 Z_t^*$$

By continuous forward substitution and leading one period:

$$P_{t+1}^* = \pi_2 \sum_{s=0}^{\infty} \pi_1^s \cdot Z_{t+s+1}^* \quad (2.18)$$

The specification of the exogenous process (Z_t) then becomes all-important. If a Government policy is known which determines (Z_t) then this can be used and the RE system can be reset as a control problem offering open and closed loop solutions (Intrilligator 1971). Alternatively, an autoregressive or more general ARIMA (Autoregressive Integrated Moving Average) process can be defined for (Z_t) from which a RE of the exogenous process can be formed.

Hence suppose

$$Z_t = \phi Z_{t-1} + \epsilon_t ; E(\epsilon_t) = 0$$

$$Z_t^* = \phi Z_{t-1}$$

then

$$Z_{t+1}^* = \phi Z_t^* = \phi^2 Z_{t-1}$$

and

$$Z_{t+s+1}^* = \phi^{s+2} \cdot Z_{t-1}$$

.....by the Chain Rule of Forecasting (See App.1)

Now

$$\sum_{s=0}^{\infty} \pi_1^s \cdot \phi Z_{t+s+1}^* = \sum_{s=0}^{\infty} \pi_1^s \phi^{s+2} Z_{t-1}$$

and

$$\sum_{s=0}^{\infty} \pi_1^s \phi^{s+2} = \phi^2 + \pi_1 \phi^3 + \pi_1^2 \phi^4 + \dots \quad (2.19)$$

$$\sum_{s=0}^{\infty} \pi_1^s \phi^{s+2} - \phi \sum_{s=0}^{\infty} \pi_1^s \phi^{s+2} = \phi^2 \quad (2.20)$$

$$\sum_{s=0}^{\infty} \pi_1^s Z_{t+s+1}^* = \frac{\phi^2}{1 - \phi \pi_1} Z_{t-1}$$

Thus

$$P_{t+1}^* = \frac{\pi_2 \phi^2}{1 - \phi \pi_1} Z_{t-1} \quad (2.21)$$

and substituting back into the structural form (equation 2.16) gives

$$Y_t = \frac{\alpha \pi_2 \phi^2}{1 - \phi \pi_1} Z_{t-1} + \beta Z_t$$

and

$$Y_t = \frac{\alpha \delta \beta \phi^2}{1 - \phi \alpha \delta} Z_{t-1} + \beta Z_t \quad (2.22)$$

$$P_t = \delta Y_t \quad (2.23)$$

$$Z_t = \phi Z_{t-1} + \epsilon_t \quad (2.24)$$

In order for a RE solution to hold (in this case) two convergency conditions must be satisfied. Firstly, in order to get from equation 2.18 to 2.21 we require that the parameter π_1 be less than unity in absolute value. Secondly, the parameter ϕ must also be less than unity in absolute value if equation 2.20 is to be valid. That is, the geometric series (equation 2.19) must be convergent.

The RE 'equation', or restriction, in our equation system, is given by the coefficient on Z_{t-1} in equation 2.21. This is the testable aspect of the theory in its econometric form. Although quite complicated for a relatively

simple system it is actually identified. Basically, all that is required is that there are at least as many exogenous variables as there are endogenous expectations. Wallis (1980) provides the definitive discussion on this. Thus, if the system is estimated as

$$Y_t = \Gamma_1 Z_t + \Gamma_2 Z_{t-1}$$

$$P_t = \Gamma_3 Y_t$$

$$Z_t = \Gamma_4 Z_{t-1} + \epsilon_t$$

then only alpha needs to be defined: other structural parameters being immediately identified. It can be easily verified that

$$\alpha = \frac{\Gamma_1}{\Gamma_3 \Gamma_4 (\Gamma_1 + \Gamma_2 \Gamma_4)}$$

2.5 A Synthesis

We have examined the components of the analytical structure which comprise decision-making in a risky environment. It was suggested that risk may be evaluated by probability or non-probability methods and we investigated how competing theories would arrive at measures of risk. This represented a 'body of knowledge' or experience concerning the risky environment of the past and we indicated that this evidence may then be used to form opinions concerning what risk is likely to be in the future.

Future or subjective risk, as an aid to decision-making, must then be related to the risk-preferences of the individual. If a strategy is to be implemented

with risk considered as a potential influence then the farmer must be aware of what level of risk is acceptable (for aversity) or required (for risk-prone individuals) so that appropriate decisions may be made. Risk may be related to preferences in a variety of ways and we have examined how differing methods (Expected Utility, Stochastic Dominance, Shackle, etc.) process such information so as to formulate decision strategies.

Should market-level decisions be required then our analytical method must be aggregated from the individual and relevant aggregation rules derived or assumed.

For specific measures of risk at the market level, such as variance, we have to decide whether stationary or moving risk is appropriate. Should the latter be chosen then we have to define expectations rules so that the farmer knows when to change opinions concerning risk. This has been emphasised in the discussion and the theoretical aspects of the major expectations hypotheses that we shall use to define moving risk has been fully outlined.

CHAPTER 3

THE STRUCTURE OF STORE LIVESTOCK MARKETS

3.1 Introduction

The most salient feature of any store market is that farmers enter each side creating both supply and demand; store animals represent intermediate goods as the output of one operation to the input of another. We can examine the structure of trading relations on the basis of the supply and demand approach although a more fundamental review will require that the temporal nature of the market be identified.

3.2 General Economic Background

3.2.1 Supply

The supply of store animals arises partly from those farms which rely on their breeding policies to derive income from the sale of stores. In the case in which supplying farms have the potential for finishing or keeping milking stock it may be that their own optimal stocking rates dictate whether sales of stores should take place. The decision will relate to capacity and to the ability of the farmer to feed his stock at reasonable prices.

Capacity constraints operate in conjunction with other influences which can be neatly categorised into short and long-term reactions. In the short-term, the farmer who rears and supplies stock will consider the expectation of future demand as an indication of how profitable sales of store animals are likely to be. Few generalisations can be made as the effect of the expectation of future demand will vary from farmer to farmer. If movements in price are representative of demand conditions (a presumption of inelasticity

of supply) then currently low prices may enter expectations so as to lead to herd or stock retentions, or may lead to more aggressive marketing techniques (e.g. selling via an intermediary). Currently high prices may enter expectations so as to lead to retentions if the high prices are used to finance herd expansion.

There will also be expectations concerned with the amount of winter fodder available for grazing animals and also with respect to the price of feeding-stuffs. Feedgrain prices may reflect a shadow cost of grazing and is in effect one element of opportunity cost that pervades the whole structure of store production. Another example of opportunity cost is that the supply of store animals may face a reserve demand from their owners (the store supplying farmers) should store prices be inadequate or if, for some other reason, store suppliers find it inappropriate to finish or milk their own stock.

A well-structured and inexpensive feeding system is a prime influence on profitability in store supply. Its utilisation, however, is another question. Uncertain results from grazing typically inhibits farmers who turn to concentrates where output response is more predictable.

In the longer term, it is likely that the farmer will consider the profitability of the entire operation in order to set the general level of output, but this process will only indirectly affect the shorter-term decisions concerning sales from month to month. Decisions concerning the general level of output will relate to the inherent productivity of the farm and to the likely buoyancy of the market in years to come.

3.2.2 Demand

The demand for store animals must rest on the expected costs involved in feeding the stock, on the expected revenue from its final sale or contribution to milk production, along with expectations concerning the sale value of any progeny. The farmer who purchases store stock will be capacity constrained to the extent that the animals must be at or near a finished state to realise their full contribution to income. He must make sure that any new stock bought-in can be catered for in the feeding regime he is operating. The farmer will have an idea of the number of animals that are due to leave the herd within the following weeks hence he will know how many bought-in animals can be accommodated in terms of grazing land or yard capacity. This is not such a strict constraint on the supply side since stock may be sold at a number of different points in their degree of maturity, although exactly how much room for manoeuvre exists will vary from system to system.

3.2.3 Prices

There is an efficient allocation of resources through the store pricing system since the auction mart which is the primary marketing outlet for most farms is itself fairly competitive. Speculation does exist but its effect is to align varying expectational processes in the role of an arbitrageur establishing a unique price.

Concentration amongst farmers on either side of the store market could bias price away from its competitive position. However, as there are numerous buyers on the demand side (for it is individual farmers who wish to buy stores who comprise the main element of demand) and since there are numerous and disparate sellers whose activities are never likely to be co-ordinated (i.e. price collusion) on the supply-side, then there is little reason to suspect that a free market price has not been established.

It is probably true to say that the activities of dealers and agents are more prominent on the demand side than on the supply side of the store market.

Their influence is ambiguous: there may be collusion and an element of price-setting but this cannot be sustained in the larger markets. In the end they, too, must sell their stock either to other markets or to the farmers who have commissioned them.

Prices in the store market depend upon expectations concerning fatstock markets. If the latter are adversely affected by concentration among buyers then this will depress the profits on finishing, for instance, for it will reduce the feeding farmer's margins by artificially depressing fatstock prices.

The evidence that exists on concentration in fatstock markets (Bateman et al 1971), in general, suggests that a significant degree of imperfection may exist. Expressed as a proportion of the purchases of the five largest buyers, concentration ratios can often exceed 70% of the size of market throughput with an inverse relation with market size. Market size will also influence the degree of concentration in the store trade although the market has to be fairly small in order for this to be important.

3.3 Government and EEC Policy

The most important feature of official policy affecting agricultural markets is the overhaul that took place in market regulation when the UK joined the EEC in 1973. Our study period covers 1970-1980 and encompasses both official regimes.

Government intervention prior to 1973 had been based on the stated objectives of maintaining a 'stable and efficient agricultural industry' outlined in the Agriculture Acts of 1947 and 1957. In general, the main policy tool was to be based upon a system of guaranteed prices adjusted explicitly (for milk)

and implicitly (for meat) to standard quantities produced combined with a deficiency payments scheme.

Price guarantees were mainly supplied through fatstock guarantee arrangements to beef, sheep and pigs. For milk they were channelled through the Marketing Boards. The analysis of the effects of official intervention on the store markets must then be primarily approached from the point of view of those farmers who are directly affected by official policies. Feeding farmers will be the main group affected although this does not rule out policy influences on the store supply side itself (subsidy payments, for example, may be important).

The Fatstock Guarantee Scheme was not the only source of intervention since various other measures provided for subsidies to be paid to farmers such as fertiliser, Hill Sheep and Hill Cow subsidies. Moreover, resource reallocation measures, such as beef and calf subsidies, were in operation to attempt to redirect output away from milk production, where over-supply was common, towards meat production.

It is unnecessary to go into any great detail about arrangements within the CAP for regulating markets as this information is well-known and widely available (Fennell 1979). What must be emphasised is the importance of the intervention price as the effective central policy tool, and its use as an economic indicator. Theoretically, the focal point of intervention measures should be the Guide Price which is set against 'normal market conditions'. But this is often an impracticable indicator since 'normal market conditions' seldom exist, hence the importance of the intervention price.

Grants and subsidy schemes are also implemented within the CAP and effectively reproduce the situation that existed prior to 1973. The subsidies are characterised by their offsetting nature with support measures: on the one

hand the Community is obliged to maintain agricultural production in all areas, whilst on the other hand it attempts to direct resources away from chronically over-supplied sectors by means of subsidy incentives (e.g. Suckler Cow Premium Scheme, headage payments in Less Favoured Areas, etc.).

The Beef and Veal Regime and the policies relating to regulation in the Dairy sector have been effective since UK membership of the EEC began. The five year transitional periods governing the rates at which the new policy regimes were implemented will have had no effect unique to itself in the beef and dairy sectors, for the purposes of our own analysis, since what took place in 1973 was a substitution of policy tools with similar objectives. That is, the purpose of the two sets of policies (before and after 1973) is to regulate the meat and milk markets. The Fatstock Guarantee Scheme operated on the basis of controlling prices whilst CAP is mainly affected through quantity (intervention) mechanisms. It should be noted at this point that CAP milk market policy is concentrated on the Dairy Products industry which, indirectly, influences the amount of milk produced.

The effect of the price or quantity approach to market regulation is to influence profitability in the two sectors. Exactly how this affects risk perception will be explained in Sec. 4.2.3 whilst the implications for the store livestock industry will be left for the empirical results to establish in Chapters 6 and 7.

The full EEC regime for live pigs came into operation in July 1967 at the same time as the common regime for cereals. This emphasises an underlying feature of the EEC pigs regime; pig meat is treated as a 'cereal based product' and there are close links between the cereal and pig meat regimes.

The EEC pig meat price is supported in three ways. Firstly, there are internal market support measures to remove surplus supplies from the Community market; secondly, there is a system of sluicgate prices and levies on imports from outside the Community and thirdly, there is a system of refunds on exports to non-EEC countries.

The first and third measures are common to most regimes and will therefore not be discussed. We turn our attention to sluicgate prices and import levies.

The sluicgate price is fixed at a level which reflects the 'world' cost of producing pigmeat. This takes into account cereal and other feedingstuff costs on the world market (MLC 1979). Furthermore, the sluicgate prices and import levies are adjusted each quarter on the basis of cereal prices during an earlier reference period.

Thus, profitability in the pig industry, including influences on the store sector, is subject to official policy affecting both fatstock and feed prices. However, prior to 1973, prices were also adjusted for changes in feed costs along with adjustments for a forecast of the number of pigs likely to receive subsidies in each forthcoming year (HMSO 1969-1973). It is true to say that both EEC and domestic policies do not take account of feeding sources other than grain and grass (e.g. potatoes, swedes, etc.) which may occasionally be fed so that feed costs can still vary independently of official policy. Moreover, since EEC support of the pig sector is based primarily on the sluicgate price, and hence international trade, it would require a very aggressive export effort on the behalf of EEC pigment producers for this to be effective.

A common regime for sheep was only established on the 20th October 1980 and therefore lies outside the purview of this study. The Fatstock Guarantee Arrangements were effective before this date along with domestic subsidy policies

Throughout the eleven year period 1970-1980 support measures for the livestock industry were frequently used as evidenced by the expenditure figures, before and after EEC membership, in Table 3.1.

TABLE 3.1 ESTIMATED EXCHEQUER SUPPORT, AND MARKET
REGULATION COSTS UNDER CAP. £'s Million

	Implementation of Price Guarantees			Market Regulation under CAP	
	Cattle	Pigs	Sheep	Cattle	Pigs
1959/70	26.2	17.4			
1970/71	31.0	7.5	9.7		
1971/72	2.8	26.3	16.4		
1972/73	1.0	2.7	1.9		
1973/74			..	1.2	19.0
1974/75			8.5	63.7	24.1
1975/76			7.5	113.0	38.6
1976/77			0.2	16.3	12.3
1977/78			0.4	11.4	-0.2
1978/79			0.1	-20.8	0.2
1979/80			11.1	10.3	0.5

Source: HMSO 1970-1980

.. negligible amount. Market regulation under CAP for cattle refers to beef and veal. Market regulation under CAP for pigs refers to pigmeat.

The figures for CAP regulation in Table 3.1 are made up of several elements and include import refunds (net of export levies) on intra Community trade, import and export refunds on third country trade, the beef premium scheme, aid for private storage and animal feed, certain production subsidies (already outlined) and the net cost of commodities bought into intervention

and subsequently sold. The negative figures for CAP pig and cattle regulation in 1977/78 and 1978/79, respectively, are due to negative net figures in, for example, import refunds against export levies.

The effect of EEC policies on the store trade, from the point of view of the stabilising objectives of EEC agricultural policy, would be to provide relatively more stable market prices for end-products than in the free market case. This is the same criterion under which the Fatstock Guarantee Schemes operated. We have seen from Chapter 2 that variation in its many forms (variance, standard deviation, etc.) is a fundamental measure of risk, and if official policies promote or affect stability in the markets then this will have implications for risk perception. We will see how official policies are likely to affect risk perception in Sec. 4.2.3 and this will be supported by empirical results in Chapter 6.

3.4 Beef

The adaptability of beef production is due to the fact that the process can be divided into a number of parts which can generate income quite independently of the other. In defining production systems to establish the economic framework we adopt the classification used by the MLC (1976), but accept that it is by no means a complete description of British beef production.

3.4.1 Biological and Economic Structures

The store beef market is recognisable as a fundamental component of the industry. The well developed market system in terms of the number of sale or purchase points results in a complex vertical structure.

Suckler herds, for instance, represent the primary source of supply of cattle to the store markets since they are mainly geared towards producing weaned suckled calves at 6-12 months of age for further rearing. In some herds the

calves are carried through to slaughter whilst in others they are held beyond weaning for sale as stores. The basic determinant of what occurs will depend on the feeding regime available to the farmer which, on a national basis, will be largely determined by the location of the farm in the hill, upland or lowland areas.

Expectations about store prices which influence the level of store sales have wider implications than merely governing the supply of store stock to finishing enterprises. Since suckler production operates over a relatively short time span, variations in returns from the market will have immediate effects on production levels if profitability is to be maintained. It will also be a considerable force in determining the size of the breeding herd via sales or retentions of heifers. An end-sale point also exists for the market in slaughtered calves which can be used as a dumping ground for unsold animals on the store side if they are in a saleable condition.

In enterprises specialising in the finishing of suckled calves and stores grazing quality is relatively more important since the stock fattened are basically the lighter counterparts in a batch of autumn-born yearlings which are stored through the winter and finished on grass at 18-24 months. Low cost winter rations are complementary to this as grass finishing relies on the compensatory growth resulting from that development in weight which has been held back over winter. Allied to this is the ability of the farmer to produce grass of sufficient quality and at the right time to enable a particular batch, say, to meet the date of an auction fair. This combination of factors, which is dominated by minimising the cost of winter keep, would appear to produce the most profitable store finishing enterprises, evidence of which has been recorded by Allen and Kilkenny (1980).

Although integrated beef enterprises of various sorts exist which both rear and fatten stock (20-24, 18 month grass/beef systems and 15 month grass/cereal beef) they do not reflect the clear motivation for purchasing store stock as do cereal beef farms.

The most intensive form of beef production depends on the use of high cost concentrate diets which promote rapid liveweight gains so that cattle are slaughtered between 10-12 months. Cattle purchased into this system are usually dairy bred calves and are generally referred to as barley beef which, these days, is something of a misnomer. The obviously short production period concentrates the influences that all finishers face. Profitability is clearly dependent on turnover since margins are squeezed as a result of the expenditure on artificial feed. Returns are also extremely sensitive to the level of buying-in prices of stock and to any adverse variations in the fatstock markets. Because economies of scale are potentially substantial a significant degree of fixed investment is required to exploit the opportunities. Fixed investment will be mainly in terms of yarding and will depend on the farmer's view of the longer-term viability of the operation which, in turn, rests on the maintenance of the feeder's margin.

The dairy sector requires special consideration in this section because of the close connections between the markets. Up to 65% of UK beef originates in the dairy herd, with this figure rising to 72% in England and Wales alone (Gardner and Walker 1969). The simultaneity of the relationships between the two markets rests mainly around the concept of input/output flows within the breeding stock. This has been investigated elsewhere by Rayner (1975) and Wildgoose (1978). Their work suggests that the interactions of the milk/beef price ratio endogenise the dairy breeding herd in relation to the size of the beef herd. That is, the two are inextricably linked (Sec. 3.5.1).

3.4.2 International Trading

International trading plays a significant role in beef production through the store markets. It is primarily concentrated on the import side in the UK (Table 3.2).

TABLE 3.2 IMPORTS AND EXPORTS OF STORE BEEF, AND THE
LIVESTOCK TRADE BALANCE (Numbers: 000's)

	1976		1977		1978		1979		1980	
	I	E	I	E	I	E	I	E	I	E
Steers	97.2	1.7	235.3	1.7	260.4	6.7	128.8	5.8	172.9	5.6
Heifers	22.7	1.0	67.0	1.0	88.1	2.4	38.9	1.5	34.9	1.5
Total Stores	119.9	2.8	302.3	2.8	348.5	9.1	167.8	7.3	207.9	7.1
Total beef livestock	229.3	297.3	304.0	511.2	353.2	521.5	169.6	506.5	220.5	370.4

I = Imports. E = Exports. Source: Dept. of Trade 1976-1980. Steers and Heifers data not collected separately before 1976. Figures for Totals may not correctly add due to rounding.

The Republic of Ireland is virtually the only source of supply of live cattle with the market share of imports throughout the 1970's not falling below 99%. This is a result of two factors: firstly of historical precedent since the Republic is traditionally the UK's main agricultural trading partner; and secondly, of disease restrictions (e.g. foot and mouth) which precludes importation from other sources.

The relations governing the level of imports of store cattle have been subject to a number of studies. Probably the most important factor influencing the decision to buy store cattle from overseas is associated with the relative price of Irish to British stores. However, Murray (1931) also found fodder

availability to be an important variable in an early statistical exercise investigating the number of imported cattle. Slattery (1966) came to a rather different, but not contrary, conclusion. She found from a model explaining imports that, along with the availability of fodder and the returns to British farmers for the sale of fat cattle, the number of store cattle available from mainland sources determined most of the variation in the numbers imported. As a result of this it was reasonably concluded that the level of imports are demand determined.

However, the store trade position does not reflect the trade balance in general. From the total livestock trade figures in Table 3.2 it is clear that exports are the dominant feature. The probable reason for this apparent paradox is that most livestock imports into Britain are, in fact, stores which require further fattening. On the other hand, exports are likely to be slaughtered immediately on arrival at their destination whether as veal or beef. Hence, the total livestock trade balance is composed of two quite separate elements: relatively younger (calves) and older (fatstock) animals are the main exports, whilst the middle-range (stores) are imported.

We have suggested that store imports are primarily demand determined, but this is not to say that a clear motivation did not exist on behalf of Irish farmers to export. Up to 1973 Irish producers were eligible to receive deficiency payments from their stock sold in the UK under the Fatstock Guarantee Scheme subject to a cattle residency requirement of two months (Anglo-Irish Free Trade Agreement). Any subsidies that were payable for fattening cattle in the UK appeared to be transferred to the Republic via the prices obtained for exports. Prices were therefore relatively favourable in the UK for Irish stores. In fact, Power (1967) estimated that up to 85% of the beef cow subsidy paid on Irish store cattle fattened in Britain returned to the Republic. Furthermore, the number of stores exported had no effect on British prices lending force to the argument that imports are demand determined (Irish producers can supply as much as they can with no immediate effect on price; in other words, they face constant marginal revenue over a certain range).

3.5 Dairy

The major characteristic of the store dairy market is its link with the production systems in the beef industry. However, in as much as the store market is a significant component of the dairy industry, it should not be taken to indicate that a parallel structure with the beef sector exists.

This is because the number of enterprises that are vertically related within the dairy industry, compared with the beef sector, are few. This may pose certain problems for the identification of a store dairy market price, but we shall see that the dairy industry has a number of distinguishing features in its production structure that support store trading.

3.5.1 Biological and Economic Structures

Heifers and down-calvers represent the main focus of attention in the store dairy market. The extent of trading has been investigated by Luxton (1976) who suggests that up to 13.4% of heifers entering dairy herds are purchased from various sources (whether by auction, contract or by private arrangement), and that up to 30% of dairy herds in England and Wales are involved in systems of purchasing herd replacements. But this only reflects the conditions on the demand side: since the store price represents the reserve price for some suppliers there may be a much greater number who are potential participants in the market.

To identify the source of supply of store stock is rather difficult since most farms have integrated rearing and milking systems with up to 70% being self-contained. Out of this group, however, only 38% have no surplus heifers for sale (Luxton 1976). That leaves four possibilities for the identification of store heifer supply:

- 1) farms with surplus heifers for sale
- 2) heifer supply from non-dairy sources (mainly beef).
- 3) supply from rearing farms only: i.e. non-milk producing
- 4) contract-rearing of dairy heifers (very small: approx.
0.2% of all heifers sold, Luxton 1976).

Heifer rearing relies on the existence of demand for replacements from milk producing farms and may therefore be regarded as a servicing activity.

A significant demand for purchased replacements arises from those farms which are expanding in terms of herd size (Table 3.3). This suggests that growth of the farm cannot be sustained by integrated rearing policies alone, or is at least too slow.

TABLE 3.3 METHOD OF STOCK REPLACEMENT IN DAIRY HERDS
BY RATE OF EXPANSION

% Change in Herd Size 1963/4-1971/2	Method of Expansion		
	<u>Home Rearing</u>	<u>Purchasing</u>	<u>Both</u>
	%	%	%
Less than 25	78	9	13
25-49.9	77	6	17
50-99.9	69	13	18
100-149.9	60	16	24
150-199.9	57	14	29
200+	34	27	39
All Herds	62	15	23

Source MMB (1973)

The question of herd size is inherently dynamic and is subject to the influence of variations in key indicators in other markets. Whilst the influence of the beef market has already been mentioned it is worthwhile pointing out some of the more important connections from the dairy side.

The effect of the milk/beef price ratio on dairying is one of the well established mechanisms in agricultural economics. Its primary influence, should the ratio change, is to re-structure temporal relations between the beef and dairy industries. That is, the ratio will determine the structure of time horizons involved in the calculation of profitability. For example, should the milk beef price ratio fall, it may only pay to keep cows in the dairy herd for a relatively shorter period of time. Marginally productive cows are then seen as more profitable in terms of beef than in terms of continued milk production.

The effect of a fall in the milk/beef ratio will also be reflected in the demand for store dairy heifers. If milk production is relatively less profitable than beef production then a larger proportion of store heifers will be diverted into beef production. This may be one consequence of a fall in the ratio and will arise because milk producers require less purchased replacements and because beef producers require more stock for fattening.

The extent of trade between the dairy and beef sectors illustrates to what extent this aspect of horizontal integration has an influence on the store market. Producing beef calves on the dairy farm, for example, may provide a flexible tool whereby spare capacity may be utilised without committing resources to longer-term production. It has been estimated that six out of every ten dairy farms rear or fatten some beef cattle (MMB 1971). As to the intensity of the relationship, Jones (1961) found a complementary effect between beef and milk production in general....'The results..suggest a long-term supply elasticity from beef of at least unity and for milk of about 0.5 with a sizeable positive cross-elasticity between them of possibly 0.4 in either direction'.

The analysis of horizontal integration in relation to the store markets is complicated by the time dimension resulting in potential supply response to prices going either way. Clearly, outflow from the dairy herd is quite elastic in terms of the numbers involved to the price of beef and this may be reflected - at the farm level - in an increased demand for dairy stores to maintain stocking rates. Alternatively, increases in the price of milk will result in older cows which are due for replacement becoming marginally more profitable and will consequently remain in the herd for a longer period of time. Demand for replacements will therefore fall viewed in terms of stocking rates and the ability of the farmer to feed his stock cheaply, but will rise in terms of the relative profitability of the two enterprises.

3.5.2 International Trading

International trading relations in store heifers or down-calvers, if at all significant, is difficult to analyse because numbers will be aggregated with the general store cattle trade. Intentions about the destination of imports or exports are left unrecorded, but we may presume that some of the heifers (especially imports from the Irish Republic) do end up in the dairy herds but to what extent is impossible to say.

3.6 Pigs

Store pig supply and demand is part of a production process which is historically unstable in terms of prices and output. The purpose of this section is to suggest how this instability arises. In addition, we investigate what features of the pig production process are important in determining profitability in relation to the store market, and we examine the nature of the biological production relationships that are likely to have a bearing on risk perception.

3.6.1 Biological and Economic Structures

The feed conversion ratio is the fundamental aspect of the production process. Typically, a large throughput is required on a pig farm to maintain profitability, but this is infamously unstable (the 'hog cycle'). It would be wrong, however, to view the cycle in discrete time as the Cobweb Theorem suggests (c.f. Larson 1967) since the aggregate production process is continuous. The short term supply of fatstock can vary widely and is correspondingly reflected in the store market by the relative ease with which the breeding herd can be expanded or contracted.

For example, gilts may be either fattened or put into pig at very short notice, and since production depends on purchased feed, increased output is technically simple to achieve. The pig breeding herd is quite responsive to changing economic conditions and was recognised as such in agricultural policy in that the breeding herd was always the focus of attention for Government intervention in the past: Jones (1961) found an elasticity of response of the size of the breeding herd to Government Guaranteed Prices of between 3-10.

On a longer term basis, the farmer must also take into account likely demand over a number of farrowing periods (biannually on average) since gilt retention will govern throughput on his particular farm and may be required should demand pick up. Probably because of these unique attributes the pig market is well documented and has been subject to much scrutiny in terms of statistical analysis (Jones 1962, Colley 1966, McClements 1969, Ness and Colman 1976 and Savin 1978).

Besides variations in output the fortunes of the store industry tend to fluctuate widely and are obviously dependent on the feed situation. Pig feed is the single most important item in the cost structure accounting for up to 80% of all expenses or £68.7 per £100 of output (Burnside and Strong 1955). Any reductions in this component of costs is going to have immediate implications

for profitability and is therefore regarded as a sensitive indicator of the state of the industry in spite, as Jones (1962) suggests, of automatic adjustment in pigmeat prices in pre-EEC days and probably in spite of EEC support in the later period.

Feed conversion is a prime consideration on the supply side in that the longer the weaner or store remains on the farm the more it is costing. The usual relation exists between the quality of feed and conversion, but the choice as to what quality the farmer should use is by no means straightforward and will vary according to individual conditions.

The absolute level of feed costs depends on the size of the herd but special mixes are required by the producer in the breeding sector as part of the weaning process. This requirement has to be considered in relation to the average age of weaning on a particular farm. The trend is that weaning should take place as quickly as possible so that the sow is available for further servicing. There is a clear indication, for instance, that the number of pigs reared per sow per year tends to fall as weaning age increases. Herds weaning at 33-39 days reared 1.5 pigs fewer per sow per year than herds weaning at less than 25 days (Burnside and Strong 1955). Because of the higher productivity of herds adopting early weaning the quantity of feed required per pig varied markedly from 81 kg of feed for the herds with relatively high breeding productivity to 91 kg of feed for the less productive herds. However, because of the associated differences in weight of pigs reared, feed costs per kg of pig produced in the earliest weaning herds were higher than in herds with the highest weaning ages due to quality (and price) differences in feed.

On the demand side the tendency in feeding herds towards producing heavier animals (cutters and baconers, MLC 1980) means that feed costs are becoming that more important although much will depend in what condition the store is purchased (whether or not it is suited to fattening to a heavier weight).

Feeding herd conversion ratios have fallen over the past few years indicating a rise in productivity (Table 3.4). Exactly how to evaluate this fall is difficult to say since the factors which influence it such as feeding method (ad lib, restricted, variety of feed, etc.) are fairly evenly distributed between the top one third and average producers (Ridgeon 1981). However, since there does not exist any a priori constraint within which the feeding farmer must fatten his stock other than on the basis of cost and capacity, consideration of lower conversion rates ease many of the instability difficulties associated with the market. It will be shown in Chapter 6 that most of the concern regarding expected profitability in the short and medium term rests with what feeding costs, and their associated risks, are likely to be.

TABLE 3.4 FEED CONVERSION RATIOS IN MLC PIG RECORDED HERDS

Feed Conversion Ratio	1976	1977	1978	1979	1980
Average	3.4	3.2	3.1	3.0	2.9
Top One-Third	3.0	2.9	2.7	2.6	2.5

Source: MLC (1980)

On the marketing side we see that the store pig industry is rather different from the others studied since the main channels of sale are via private arrangements of one sort or another. Mitchell (1975) estimates that up to 67% of farmers sell their stock privately compared with 33% using the auction marts. A plethora of arrangements are likely to lie in the 67% as the majority of pigs marketed by co-operatives, feed and breeding companies are subject to contracts which would be included in this category.

3.6.2 International Trading

The level of international trade is not substantial with only 8000 pigs going for export in 1980, for example, and just over 20000 coming in (Dept. of Trade 1980). The trade is clearly import orientated although the figures quoted above (and below) refer to all sections of live trade.

Exports are a variable feature and it is difficult to be specific about destination because of the inadequacies of the data (too large an 'other countries' category). The Republic of Ireland remains, on average, the main market to which UK swine are sent with traditional ties existing between France and Italy and occasional markets arising for distinct and one-off orders such as to Bulgaria, Taiwan and Portugal.

On the import side the Republic of Ireland is the outstanding trading partner accounting for about 100% in every year. Hence the analysis of the previous sections hold.

Mention must be made of the trade in pigmeat because of the 'proximity' of the retail market to the relationships in trade at intermediate points in the production process. The main element of trade in the bacon industry, for example, emanates from the exports of Denmark to the UK. Historically, the feature of the Danish industry which most clearly emphasises its competitive force is its marketing strength. Noted for the efficient manner with which production is undertaken at all levels (NEDO 1972), Danish imports represent a significant drain on the prospective demand for UK pigmeat produce.

3.7 Sheep

The store sheep sector, together with the industry in general, has faced little in the way of fundamental change over many years. The reasons are not that difficult to find: it is not a very profitable trade, there is little scope for substantial improvement that is simultaneously cost effective and the farming conditions on which production is based are often too restrictive to facilitate any great advances.

3.7.1 Biological and Economic Structures

The traditional pattern of commercial sheep production in the UK is a system of husbandry related to altitude of grazing. Purer bred flocks are to be found in the harsher hill areas; the ewes are drafted to the lower ground for mating and eventually down breeds are mated to produce slaughter lambs, mainly on lowland farms. The process is generalised and details of breeds are to be found elsewhere (MLC 1981).

Within this framework the store sheep trade, through 1970-80, has not been a significant aspect of the industry being worth about 9% of all lamb disposals. Clearly, store sales are more significant off hill farms than otherwise although a Welsh survey (Lloyd 1977) indicates that both hill and upland sheep farms engage in store purchasing activities (Table 3.5). The store industry is not inherently a part of lamb production. It is more of an activity-by-default in that some farmers are unable to sufficiently fatten a proportion of their stock, or odd numbers of lambs are late developers, or competing enterprises on lowland farms makes sheep grazing relatively costly. If the industry is anywhere near efficient then this aspect is likely to be residual by definition.

TABLE 3.5 DISTRIBUTION OF SALES AND PURCHASES OF
STORE SHEEP IN WALES 1976

	<u>Lowland</u>	<u>Upland</u>	<u>Hill</u>	<u>Other</u>	<u>All Flocks</u>
% Total Lamb Disposal by Store Sale	1.5	8	13	1	9
% Total Farms Purchasing Stores	23	13	6	55	13

Source: Lloyd (1977)

Feed and forage costs are the major components of direct costs in lamb production. The ability of the farmer to minimise his use of concentrates will be the most significant factor in influencing returns along with producing supplementary feed to coincide with time of high production and by maintaining a tighter lambing schedule.

When grazing is generally deficient lamb output will produce a high proportion of stores to finish in the autumn and winter on a variety of crops. One potential advantage of this is that it spreads sales away from peak output/low prices in the early autumn. These matters, however, are largely out of the hands of the farmer with store output being dictated by the quality of his land, weather conditions and unexpectedly high lambing percentages.

The start of the breeding season - the date at which the rams are first turned in with the ewes - determines the main pattern of events for the rest of the sheep year. Amongst other things, breeding policy will determine the date at which the lamb crop is ready for sale and the returns from production as prices vary over the season. The relatively harsher conditions on which hill sheep are kept means that the winter feed situation on most hill farms enforces the sale of nearly all animals except from the breeding flock.

It also necessitates, in some cases, the wintering away of replacement ewe lambs. The portion of the stock which is left unfinished will be sold as stores to lowland farms although many sell unfinished stock for reasons other than to do with the physical environment (competing enterprises requiring land, for example). As grazing becomes scarcer upland farms will offload their stock the timing of which, in general, takes place at an earlier part of the year than under lowland conditions. The majority of lamb and store sales will therefore occur at about September in hill and upland areas whilst it may be extended to November in lowland regions (Table 3.6).

TABLE 3.6 PERCENTAGE DISPOSAL OF STORE LAMBS BY SEASON

Region	July or before	Aug.	Sep.	Oct.	Nov. or later
East Midland Region					
Lowland	-	28.8	33.7	22.2	15.3
Yorkshire Region					
Lowland	0.6	18.3	33.9	41.1	6.2
Hill & Upland	3.6	25.4	41.3	24.7	5.0

Source: Thomas (1976)

In the econometric analysis that follows wool is largely ignored because it is not the primary reason why lamb production is undertaken (with which we are mainly concerned), and it would be difficult to identify exactly what proportion of the value of output is attributable to wool since store and fatstock purchases implicitly take into account any income to be derived from such sales. In general, about 10% of the price of a store or fat lamb may be attributed to its fleece value (HMSO 1981).

Store sheep marketing via auction marts is inherently more important as a sale outlet than for fattened animals since the latter can either be sold deadweight or live. The advantage of the auction system for store suppliers is represented by the fact that the farmer is not committed to a transaction. Any sudden

changes in demand for certain types of stores can be adjusted to simply and quickly by withdrawing stock or marketing as the situation requires. However, the instability of the auction mart will be one reason which has promoted the growth of alternative outlets. Contractual arrangements, for instance, offer a greater degree of security of return (c.f. HMSO Barker Report 1972).

Co-operative sheep marketing is becoming more popular although co-operatives are primarily concerned with finished stock. Gosson (1977) noted that at least one co-operative specialised in breeding stock and that another dealt with store lambs in a survey in the South-West of England.

3.7.2 International Trading

The situation relating to live sheep imports in total is no different to the other livestock sectors in that the Irish Republic is virtually the only trading partner (Department of Trade 1970-80). A breakdown of this material reveals that store sheep are usually the main imported product although a near equal number of lambs are brought in (Table 3.7). About 10% of the total imported are used in the breeding stock whilst only a small proportion (about 2%) come in as fat sheep.

TABLE 3.7 IRISH SHEEP EXPORTS TO THE UK (% TO TOTAL EXPORTS),
AND THE TOTAL LIVESTOCK TRADE BALANCE (Nos. 000's)

	1974	1975	1976
Breeding Stock	10.0	10.0	9.2
Fat Sheep	2.7	2.9	2.0
Store Sheep	46.7	44.2	47.3
Lambs	40.1	42.5	40.1
Total Live Sheep Imports	67.2	77.9	79.8
Total Live Sheep Exports	81.1	235.4	322.4

Sources: Irish Livestock and Meat Board (1977) & MLC (1977)

Exports of live sheep are primarily sent to two sources. The Irish Republic was the main, but not the sole, destination to which UK live sheep were sent. The French market has played an increasing role as an export outlet but has always remained in a difficult position in that a number of trade restrictions (at one time or another) have been effective during our study period. For example, some exports to France of stores (and sheep for slaughter) were not permitted for a short time after 1973 because it had not given the Balfour Assurances for sheep (Volans 1975) which resulted in a suspension of the issuing of new licences for export. There also existed difficulties over market practices in France concerning official decisions on import requirements. A quota system operated which was based on the distribution of licences which were valid for only one week from the date of issue. This resulted in export arrangements becoming extremely complicated as time was of the essence. Consequently, a system of contracts developed although uncertainty concerning movements in exchange rates made this rather a risk-prone activity.

CHAPTER 4

MODELLING PRINCIPLES

4.1 Introduction

Throughout the analysis, variance-based measures of risk will be employed. The exact approach will vary from model to model and is fully outlined in the relevant empirical sections. A more general introduction is provided here along with a justification and examination of the assumptions underlying the modelling approach.

4.2 The Modelling of Risk

4.2.1 The Utility Base

Risk analysis can be fully justified within the Expected Utility Theorem examined in Chapter 2. The first step is to assume that utility is cardinally measurable in the sense of Ramsey (1931), Von Neumann and Morgenstern (1947), Savage (1954) and Bernoulli (1954). (See App.2 for assumptions). Preferences over risk can then be given unique measurability up to a linear transformation of utility (for example, $U_2 = a + b U_1^2$ is an invalid transformation).

Suppose utility to be a sole function of income $U(Y)$. The characteristics of the function are such that the individual prefers more income to less, ($U'(Y) > 0$). The level of income obtained depends basically on the amount of effort extended and the degree to which resources (for a producer) have been committed to production but it is also assumed to be subject to stochastic influences. The greater the commitment to production the more investment is required. Assume a probability of a 10% variation in returns to production (income) in any one year. We know that a probability measure can be assigned

to any uncertain situation which may be faced irrespective of the existence of historical information by the analysis of Chapter 2. Given a 10% variation in income (5% either way) the farmer will observe that 10% of 1000 bushels of wheat is greater than 10% of 100 bushels. The question then arises as to whether a potential loss of 5% of 1000 is regarded as equivalent to a potential loss of 5% on 100 bushels.

This problem can be solved after an examination of the farmer's utility function. If 5% of 100 is considered to be more serious than a loss of 5% of 1000 bushels then the utility function of income will exhibit concavity. Even though greater levels of income are possible from producing 1000 bushels of wheat the extra income does not offset the associated increase in potential loss of investment expenditure hence marginal utility tails-off: that is $U''(Y) < 0$. This is a representation of risk-aversity in utility terms and is measured by the rate of change of the function. For a risk-prone person we have $U''(Y) > 0$; for a risk-neutral person we have $U''(Y) = 0$. The second derivative of the utility function does not, however, provide a unique measure of risk aversion because it can be arbitrarily multiplied by any constant. Consequently, Pratt (1964) and Arrow (1965) working independently suggested the following measure of risk-aversity in utility terms:

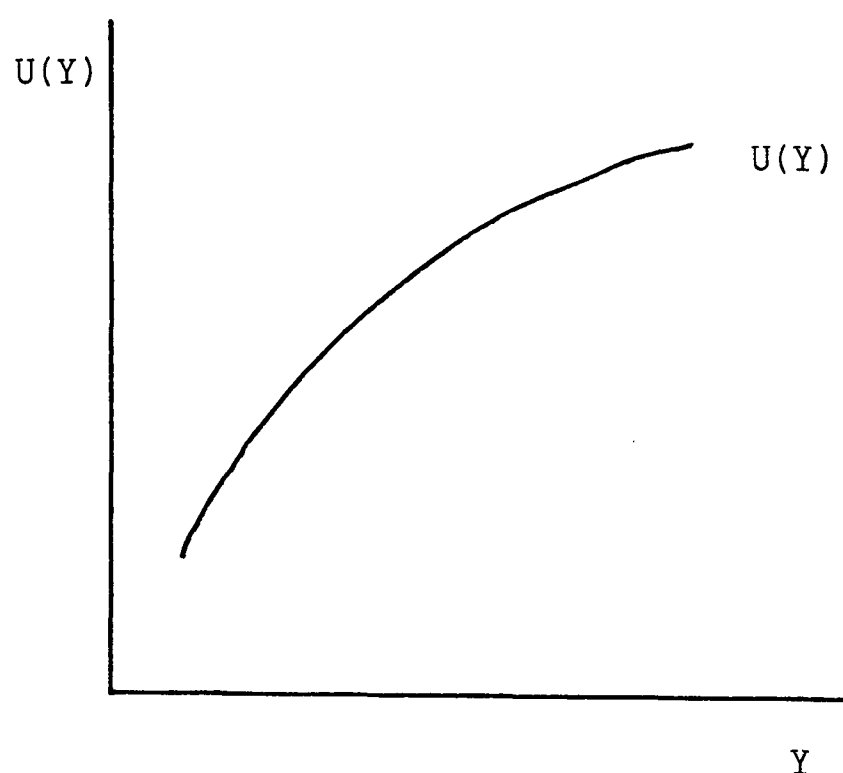
$$R_A = \frac{-U''(Y)}{U'(Y)} \quad (4.1)$$

This is known as the absolute measure of risk aversion, though in itself, it does not make any sense unless it is related to a given scale of measurement (rather like a coefficient in a regression equation). It is readily seen that the measure can be converted into an elasticity (and hence become independent of the units of measurement) by multiplying by any given income (See App. 2).

$$R_R = \frac{-\bar{Y} \cdot U''(Y)}{U'(Y)} \quad (4.2)$$

This is known as the coefficient of relative risk aversion. For both measures $R > 0$ implies risk aversity ($U'(Y) > 0$ assumed; therefore $R > 0 \Leftrightarrow U''(Y) < 0$). The other characteristics follow immediately. R is larger for a more risk-averse individual than for one who is less risk-averse and the measure is unaffected by any arbitrary linear transformation of $U(Y)$. The nature of the risk-averse utility function is shown graphically:

FIGURE 4.1 THE UTILITY FUNCTION FOR A RISK-AVERSE INDIVIDUAL



For the analysis to be accurate it must be accepted that the Arrow/Pratt measure of risk-aversity is only a local one and may not necessarily be globally relevant.

4.2.2 Functional Form

To establish that variance might be a significant feature of risk response in the framework we have examined a particular form of the utility function is assumed which has been well-used in practice (Hey 1979). For example, suppose that

$$U(Y) = a - be^{-RY} \quad (4.3)$$

This is known as a constant absolute risk utility function where R , the absolute measure of risk-aversion defined above, is set to a given level. The equation 4.3 can easily be verified as having constant absolute risk by integrating the definition $R=U''(Y)/U'(Y)$, or equivalently, by showing that $R=U''(Y)/U'(Y)$ can be established by differentiating equation 4.3. Thus if

$$U(Y) = a - b e^{-RY}$$

then

$$\frac{dU(Y)}{dY} = b R e^{-RY}$$

and

$$\frac{d^2(U(Y))}{dY^2} = -b R^2 e^{-RY}$$

by the function of a function rule of exponential differentiation (Bunday and Mulholland 1967). Thus

$$\frac{-U''(Y)}{U'(Y)} = R$$

where R is set to a constant level.

Variance can then be established as an important property of risk analysis by examining the implications to be drawn from equation 4.3. If, to be relevant to our own investigation, we assume that the sole argument of the utility function is profit instead of income then taking expectations of equation 4.3:-

$$E[U(\pi)] = a - b E[e^{-R\pi}]$$

where $E[e^{-R\pi}]$ represents a moment generating function (mgf) for stochastic profits defined as

$$m(-R) = E\{e^{-R\pi}\} = \int_{-\infty}^{\infty} e^{-R\pi} \cdot f(\pi) d\pi$$

and for the example in question we have (Hogg and Craig 1970)

$$E\{U(\pi)\} = a - b \cdot \exp(-R\mu + \frac{1}{2}R^2\sigma^2)$$

where the expression on the RHS in brackets results from a Taylor's expansion about the mean ($U(\pi)$ is assumed continuously differentiable, $E(U(\pi))$ is assumed log-normal and π normally distributed (Aitchison and Brown 1957)). Maximisation of Expected Utility is then equivalent to maximising the expression $\mu - \frac{1}{2}R\sigma^2$ for positive profits (because we minimise the amount to be subtracted from the constant for $b > 0$).

Variance is therefore a reasonable approximation to risk when the utility function is of the form 4.3. If variance is to be used as a total measure of risk then the underlying distribution of the stochastic variable must be normal (hence fully specified by the first two moments of its distribution) or, alternatively, that the utility function is quadratic in stochastic profits, for example

$$U(\pi) = - (a - b\pi)^2$$

and the absolute measure of risk aversion is:-

$$\frac{-U''(\pi)}{U'(\pi)} = \frac{1}{a/b - \pi}$$

which gives expected utility equal to

$$E U(\pi) = U(\bar{\pi}) - \frac{1}{2}\text{Var}(\pi)$$

and suggests that as variance increases then expected utility falls. The negative sign on variance is assured by a negative second derivative of the utility function (See App. 2).

The implication of the quadratic utility function is that utility decreases beyond the level set by a/b : or, the absolute measure of risk aversion increases at greater levels of profit ($\pi > a/b$). Therefore, it must be accepted that the analysis is based on a local measure and set within the bounds given by $\pi = 0$ and $\pi = a/b$. The justification for the use of variance-based measures of risk rests on its validity in an empirical context if such a local and bounded measure is to be relevant and meaningful.

4.2.3 Constraints on Risk

One of the major objectives of this study is to examine what effects, if any, official policy has had on expectations and risk perception in the Store Markets. Intervention in British agriculture has been fully outlined in Sec. 3.3 but can be broadly summarised as being affected through the Fatstock Guarantee and Milk Price Schemes prior to 1973 and through the CAP of the EEC post 1973. Intervention invariably implies distortion of the market mechanism otherwise there would be no reason to intervene. It will therefore have potential implications for the analysis of risk and act as a constraint on its free-market effect.

A major free-market effect of risk for risk-averse farmers is that it lowers the effective rate of return (by the 'risk premium') which will lead to lower work effort and hence lower output (Newbery and Stiglitz 1981). But there is another argument which suggests that farmers work harder as a result of risk by attempting to provide a margin for error. This obviously confounds the analysis but is exacerbated by the farmers' perception of official intervention schemes. The Fatstock Guarantee and Milk Price Schemes fixed prices to standard quantities and a similar objective is to be found within the implementation of the CAP by intervention to maintain levels of output (Sec. 3.3). The Fatstock Guarantee and Milk Price Schemes supported prices from below, whilst the CAP has a similar consequence from the implementation

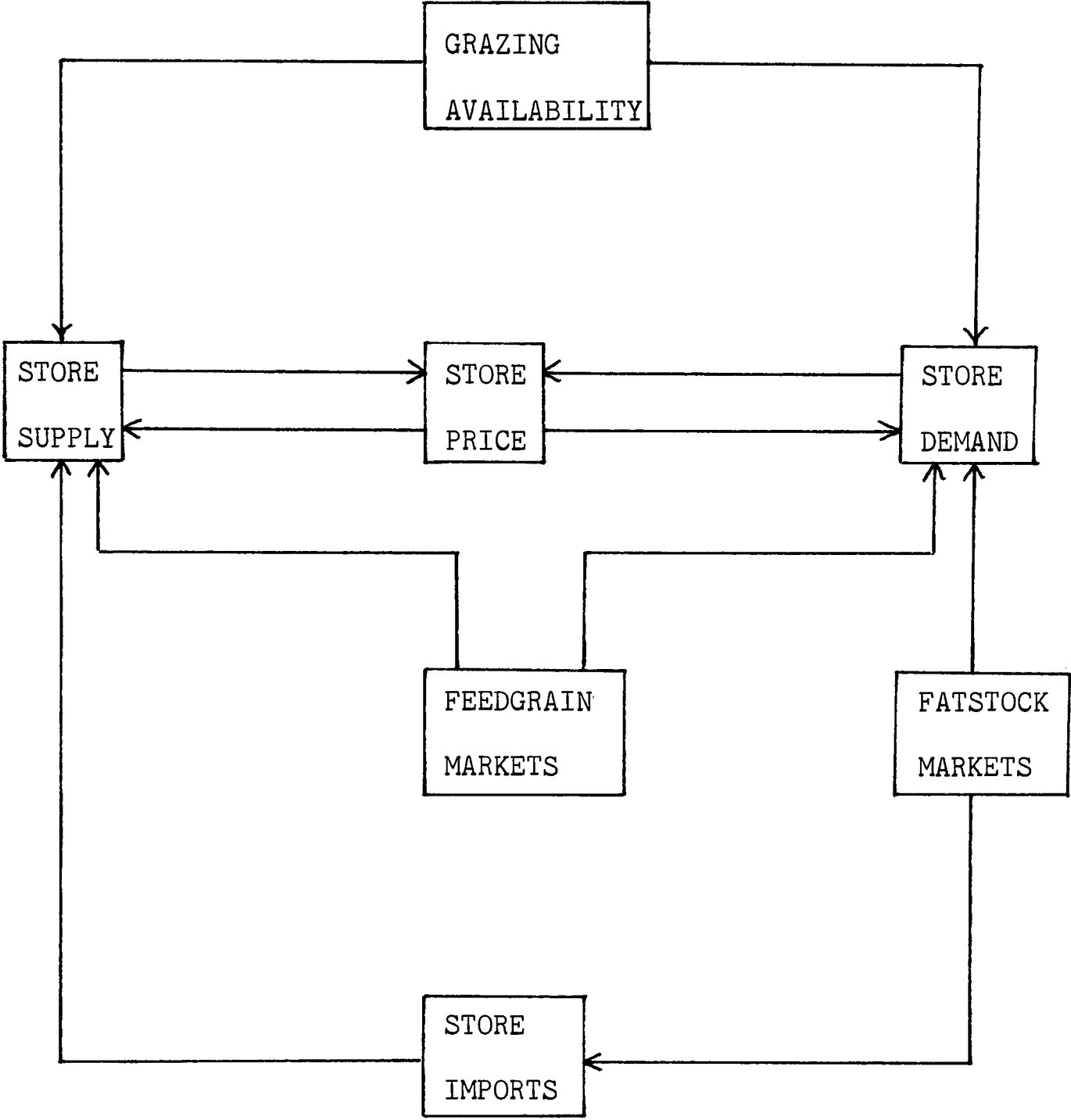
of intervention measures. This effectively provides a lower bound below which farm prices will not fall. No upper bound exists as beyond a certain price level the free market mechanism prevails which will establish market equilibrium price and hence determine supply.

This is likely to have significant implications for risk in any empirical study. Variation in price in the fatstock and milk markets below the level set by official policy is largely redundant since an effective floor exists to price and therefore variation in that direction is inhibited. This is not so for variation above the mean. The implication is that price risk may not be perceived as a symmetric phenomenon as implied by the variance measure for greater weight will be attached to positive variation (that is, above the mean). This does not rule-out risk arising from other sources such as demand uncertainty, but will indicate how official policy influences the scale of price variance (risk). We reiterate what has been previously stated: even though risk perception may be more important at one end of its distribution this does not imply that the variance measure is irrelevant because variance only evaluates the scale of risk, not its effect. The influence of the latter will be measured by the regression coefficient on the risk variable in the main equations.

4.3 The Modelling of the Store Markets

Single equation and simultaneous methods are used to identify risk in the Store Markets. The rationale for each will be found in the relevant chapters. Here a basic scheme is outlined to illustrate the method of attack on the problem at identifying the influence of expectations and risk. Figure 4.2 shows how the Store Markets are generally conceptualised with arrows suggesting direction of influence and two-way arrows implying simultaneity.

FIGURE 4.2 A GENERAL REPRESENTATION OF CAUSATION IN THE STORE MARKETS



Aspects of the Store Markets which were isolated were chosen bearing in mind model manageability. Other influences were assumed to be sufficiently insignificant so as not to unduly bias those influences modelled and to leave the structure realistic. Figure 4.2 is self-explanatory and is justified in terms of the analysis of Chapter 3. The subsequent chapters will explain exactly what exogenous processes are identifying the model, and how such economic relations can be dynamically structured.

4.3.1 The Marginal Approach

In Chapters 6 and 7 modelling frameworks will be established which concentrate on the concept of the 'marginal animal'. It has already been suggested that the Store Markets operate in such a manner that many sources of risk may be concentrated in market relations: risk from grazing; risk from the feed markets; risk from the fatstock markets and so on. We specifically model risk from fatstock and feed markets and risk arising from the Store Market itself (store price uncertainty). Grazing risk is investigated in a separate chapter.

In what follows the nature of risk is implicitly examined in the region of equilibrium but not at equilibrium. Equilibrium is quite exogenous to the decision-making process for the existence of one precludes the existence of the other (c.f. Chapter 2). Hence, the concern is with variations about equilibrium where decision-making is still a relevant concept.

These variations are small in relation to equilibrium values and are adequately captured by conceptualising risk in terms of the marginal or single animal. Thus, because the marginal animal represents a single unit of production then variations in its use which, in turn, reflect market conditions (factors determining supply and demand of stores) are implicitly in the

region of equilibrium. That is, variation in economic forces which determine store throughput on any one farm are limited to the extent that there is only a limited scope for response to changing economic conditions which can be made with the marginal animal. Thus we definitionally work in the region of equilibrium. Variations which are large in relation to normal or equilibrium output are ruled-out, a priori, on the grounds of capacity-constraints. The farmer is assumed to be working near to his capacity or where large changes of any type are excluded on the basis of cost considerations.

The meaning of the 'marginal animal' is that it is supposed to reflect small variations in farm throughput about equilibrium. We therefore intuitively model how one entrant into a store supplying farm makes its way through the system to reach the fatstock markets. On its way the factors which are likely to have some bearing on its destiny are identified.

The marginal approach has implications for model structure. We consider the effects of risk on marginal profitability and therefore assume that the farmer is a profit-maximiser. But to define profitability we would normally multiply price by throughput per production period. Once output enters the framework considerations of production possibilities must be taken into account and so the specification of a production function is required. Because production possibilities enter the analysis of profitability, then risk on profitability becomes relatively more difficult to define. Account must now be taken of price risk, production risk and joint risk between them. Price and production risk are inevitably different processes and must be specified accordingly: for a price-taking farmer, price risk is defined within the market whilst production risk is defined by the technical combinations of factors of production; that is, the production function.

If considerations of a production function arise as a consequence of defining profit as price multiplied by output then it is easy to see why the marginal animal approach simplifies the analysis. In the marginal framework profit becomes profit per animal. Profit per animal is completely specified by its price minus associated costs (feed costs, housing costs, etc.). Consequently, consideration of production possibilities is no longer necessary, for what production possibilities are there with a single animal? Not many. It is also clear to see that techniques of production are unlikely to change in the region of equilibrium within which we have assumed the modelling approach to be operating. Therefore, techniques of production (proportion of artificial to total feed fed to the stock, yarding, etc.), if at all relevant to the marginal animal, are likely to be a constant feature of store modelling.

It is assumed that in the region of equilibrium that monetary factors, as opposed to quantity influences, take primacy in determining the level of store supply and demand at the margin. That is, because the techniques of production are unlikely to change in the region of equilibrium, and because the store market is structured in terms of the marginal animal, then profitability is influenced mainly by prices and other monetary considerations. Profit per marginal animal is then equal to sale price minus feed price (as the main element of production cost) minus buying-in price (for the store purchaser).

It should now be clear why the marginal approach simplifies the analysis because the specification of a production function in order to define profitability is superfluous. The equations representing Store Market risk on marginal profitability can therefore be composed of prices only. That is not to say that quantity variables do not enter the scheme, they do, but risk is not defined by them.

The analytical approach therefore enables us to concentrate the effects of price risk, or in other words, separate its influence from other sources of variation

which are more difficult to identify such as production risk. We presume our results to be more general than the marginal approach would imply since we treat the marginal animal as if it was representative of all aggregated market conditions which, by definition, are a combination of all influences (supply and demand) which set market price.

4.3.2 The Aggregation Problem

Subjective risk as an aid to decision-making is fundamentally an individualistic concept. This fact cannot be denied or ignored. The problem for econometric analysis is how to adequately represent risk within one particular market without the consideration of innumerable utility functions.

The aggregation problem is not unique to risk analysis and Theil (1954, 1971) has shown under what conditions aggregation rules may produce theoretically valid results. Just (1974) employed Theil's results to examine the implications for risk analysis and decision-making but did not use these conclusions to develop his own empirical work. A leap of faith is required regarding the approximation of subjective risk in an aggregated framework. This has typically been the response to the difficulty in nearly every empirical application. Quite often, the microeconomic implications of the aggregation assumptions (and vice versa) concerning risk are ignored. There is no panacea to the problem and it is important to consider the implications which our own analysis has for the difficulty.

The variance measure of risk has been examined and justified (subject to its own caveats) in Sec. 4.2.1. The basis of the argument is that utility is a sole function of profit. Profit is defined in terms of prices only the reasons for which have already been explained. Consequently, utility is a sole function of prices. In fact, it is a sole function of a combination of prices (sale minus cost price), but this does not affect the generality of our argument.

The point to notice in relation to the aggregation problem is that these prices will be common to all farmers if they are assumed to be price-takers. In other words, even though individual utility functions may differ in their structure, the arguments of the functions for the marginal animal are identical. In this way risk can be approximately aggregated if utility is cardinally measurable as we assume.

For the purposes of this analysis the question which is critical for the aggregation problem then rests on whether our utility analysis is valid; that is, is variance a valid representation of risk? To the extent that the approach misrepresents the true situation then the aggregation problem is not tackled. However, it may be argued that the functional relationships describing microeconomic utility theory have the same form and implications at the macro level. This view does not rest on exact aggregation but on the view that macro relations are reasonable enough explanations in themselves in describing market behaviour towards risk. It is by no means claimed that the aggregation problem is solved but that, subject to the caveats mentioned, a viable analytical method has been established.

CHAPTER 5

RISK IN A GRAZING CONTEXT

5.1 Introduction

Grassland production is generally the cheapest method by which farmers may feed ruminant stock. The fact that grassland potential is not fully utilised is well known (Exeter 1980). Full utilisation would require investment in terms of fertiliser but the fundamental variability of grassland output makes this an uncertain proposition (Jones and Hocknell 1962, Colyner 1969 and Cone 1974).

Decisions concerning investment in fertiliser will rest partly on how grassland output is expected to respond and how risk is perceived. If a situation arising from increased fertiliser usage is considered to be one involving greater risk in terms of more variable output, then risk-averse farmers will tend to avoid such a strategy. Grazing resources will be left underutilised.

We examine whether greater Nitrogen input and greater grassland production are associated with a higher level of risk. It is an ex post analysis of risk in an actual and experimental setting. No account is given of the decision processes involved in the results for they are redundant by the analysis of Sec. 2.2. The conclusions to be drawn are pertinent only to beef, dairy and sheep systems; pigs are excluded for obvious reasons.

5.2 Variable Definitions and Data

Definitions of variables used in this chapter are:

- AABSE1 = Absolute standard errors for actual data over the average N input range 150–225 Kg/ha ('average' refers to the mean value of the two years within each pair of years 74/76, 75/77, 76/78 (See Sec. 5.3.1.1)). Group 1.
- AABSE2 = Absolute standard errors for actual data over the average N input range 225–300 Kg/ha. Group 2.
- EABSE1 = Absolute standard errors for experimental data for the N input level 150 Kg/ha.
- EABSE2 = Absolute standard errors for experimental data for the N input level 300 Kg/ha.
- APRSE1 = Proportional standard errors for the actual data. Group 1.
- APRSE2 = Proportional standard errors for the actual data. Group 2.
- EPRSE1 = Proportional standard errors for the experimental data. 150 Kg/ha N.
- EPRSE2 = Proportional standard errors for the experimental data. 300 Kg/ha N.
- N1 = Average N input for actual data. Group 1.
- N2 = Average N input for actual data. Group 2.
- R1 = Average rainfall associated with actual data. Group 1.
- R2 = Average rainfall associated with actual data. Group 2.
- DRA = Drainage index of farmland (see Table 5.1).
- DRO = Drought factor (number of days without rainfall).

TABLE 5.1 DRAINAGE INDICES OF FARMLAND

SOIL CHARACTERISTICS	CODE
Soil well-drained. No mottling down to at least 60 cm.	0
Soil imperfectly drained. Slight mottling throughout top 60 cm, or distinct gleying between 30-60 cm.	1
Soil poorly drained. Strong gleying at some level below 15 cm but little or none above this.	2
Soil badly drained. Severe gleying within 15 cm of the surface	3

Source ADAS/GRI (1980 b)

Two basic sources of statistics were used in the analysis. The more substantial derived from the Agricultural Development and Advisory Services/Grassland Research Institute (ADAS/GRI) 1980 (a) Report of the Joint Committee on the GM20 Grassland Manuring Trial which is hereafter referred to as 'experimental evidence'. The second is the ADAS/GRI (1980 b) Joint Permanent Pasture Group Report on the Factors Affecting the Productivity of Permanent Grassland which is hereafter referred to as 'actual evidence'.

5.3 Definition of Risk

Variance-based measures of risk are used throughout this chapter. The ANOVA sections assume that the variance of output can be analysed as risk or is a sufficient approximation to it. Ex post or actual measures of risk are used in all sections and hence no decision-rules and subjective measures relating risk to preferences based on expectations are required.

Standard errors of grassland output are used in the regression analysis of the actual data as approximations to risk. These are justified on the grounds of the analysis of section 4.2 where the assumption of the variance-based measure is investigated. Standard errors are used because they are felt to be more appropriate in the simple regressions to follow and primarily because they may be more accurate at capturing the linear response of grassland output to N that we hope to measure (see section 5.5).

5.4 Analytical Methods

The details of the mathematical and statistical methods used to derive the results are outlined in this section. Standard statistical results are accepted without question; variations on the theme are fully explained.

5.4.1 Analysis of Variance: ANOVA

5.4.1.1 Experimental Design and Tables of Classification

Experimental design underpins the validity of the ANOVA methods. Our investigation examines those forces which affect grassland output. ANOVA is a method by which variations in grassland output may be decomposed into its contributory influences. Exactly what influences are allowed to vary, or what variable influences are studied, defines the experimental design. In the examples presented experimental evidence is subject to variations in

- 1) the year in which the observation was made
- 2) the level of N application to the soil
- 3) the specific farm or site where the observation was made

The experimental evidence (ADAS/GRI 1980 a) is based on observations made over four years (1970, 71, 72, 73) on twenty-one sites (farms). We chose to analyse two N levels out of the three available (see below) and these are 150 kg/ha N and 300 Kg/ha N. This then establishes a fairly simple 3x3 Table of Classification:

FIGURE 5.1 FORMAT OF TABLE OF CLASSIFICATION FOR EXPERIMENTAL DATA

	Year 1		Year 2		Year 3		Year 4	
	150	300	150	300	150	300	150	300
	Kg/ha N	Kg/ha N						
.								
.								
.								
.								
.	21 Farms							
.	(Sites)							
.		(Observations:	Farms x Years x N)					
.								
.								
.								

The original 168 observations (years x farms x N levels) are Dry Matter Yield of grass/tonne per hectare.

In the experimental results only, two different N levels are used on different plots for each farm (site) so that every cell in the Table of Classification of Figure 5.1 is filled. This clearly cannot be the case in the actual data since the farmer either uses one N level or another, but not both.

Two sets of experimental results are analysed based on the method of application of N to the soil over the growing year. In Table 5.3, Pattern 1 refers to six equal applications of N. In Table 5.4, Pattern 2 refers to N application of the form $1/4$, $1/4$, $1/8$, $1/8$, $1/8$, $1/8$. This represents two out of the three variations used in the GM20 trial. The other was $1/8$, $1/8$, $1/4$, $1/4$, $1/8$, $1/8$ and is not used because it is not represented in the N group 150 kg/ha which we have chosen to analyse. The purpose of the differing patterns of N application is to test if the other nutrients added to the soil in the GM20 experiment besides N were being adequately represented and could therefore be excluded as a source of discrepancy in the results. The other nutrients were: Potassium, Lime, Phosphorous and Magnesium.

Actual evidence is also examined by ANOVA methods although the meaning of 'experimental design' has to be extended somewhat. The environment in which the study was undertaken is not controlled as in the experimental evidence hence we see that N application is of a more continual nature with ranges of application being more important to the analysis than their levels. Subject to this caveat comparisons may still be made with the experimental evidence although there is likely to be an element of residual variation - unaccounted for - which can be regarded as variation arising from the working environment: variability due to management skills, motivations, credit worthiness, etc., etc.

The same factors are identified as influencing actual evidence that have been defined for the experimental evidence. However, because the data was not organised strictly subject to experimental design (that is, precluding - as far as possible - extraneous influences) 'groupings' or 'ranges' of N application had to be made in relation to year and farm variation. Three N ranges were established: below 150 kg/ha N; between 150-225 kg/ha N; and between 225-300 kg/ha N. These roughly correspond to the set levels for the experimental data (150 kg/ha N and 300 kg/ha N) although we have added an extra group to further develop our analysis (there is no corresponding experimental N input to the 'below 150 kg/ha N' group).

The original data for the actual evidence were presented over 3 two-year periods: 1974-76, 1975-77, 1976-78, hence there are two annual observations within each pair of years. There are 402 observations available in total. The N and year categorisation automatically define which farms should be included in which category: for example, observations over the two years 1974-76 with average N input over those two years of 100 kg/ha automatically places that particular farm in the "1974-76, below 150 kg/ha N" category. This established the original nine (3 two-year periods x 3 N ranges) Tables of Classification. For example, the two-year period 1974-76, below 150 kg/ha N category would have the original Table of Classification as shown in Figure 5.2.

FIGURE 5.2 FORMAT OF TABLE OF CLASSIFICATION FOR
ACTUAL DATA. 1974/76, BELOW 150 KG/HA N

1974-76

Year 1 (74/75) Year 2 (75/76

.	
.	
.	
. Farms	(Observations = Farms x Years)
.	
.	
.	

Where each observation of grassland output in the Table would satisfy the criterion that the farm chosen used, on average, less than 150 kg/ha N over 1974-1976, it must be noted that no single farm is represented in all years and that not all farms were suitable for analysis (for instance, because of N > 300 kg/ha or equal to zero). As a result of this a total of 346 observations were used in the analysis with the numbers in each one of the nine Table of Classification depending on the farms that were suitable. As much data as possible were used (86%, in fact; further details below.)

Each observation of grassland output in the actual data is measured in terms of Utilised Metabolisable Energy (UME). The original source of information (ADAS/GRI (1980 b)) only classified output in this manner, the reason being that an index had to be defined which was sufficiently comprehensive to embrace the different types of livestock to enable a general comparison of the productivity of grassland in terms of its use as a feeding source between disparate farms. Metabolisable Energy is a description of the feeding requirement to sustain livestock (known as 'maintenance') and also to contribute to their growth (known as 'production'). Since the data related to dairy farms then maintenance and production included output in terms of milk. An explanation of the exact calculations to determine UME for different types of stock (Dairy, Suckler) lies outside the scope of this study but the

formulae used are reproduced from ADAS/GRI (1980 b) and are to be found in Appendix 3.

Utilised Metabolisable Energy is a derivative of Metabolisable Energy and is defined as:

UME from all grassland = ME requirements of livestock (the formulae on a farm shown in the Appendix)

minus ME from purchased feed

minus ME from home grown grain

minus ME from root and forage crops and purchased fodder

plus ME in conserved grass sold off the farm adjusted for differences in stocks of conserved grass at the beginning and end of the recording period

5.4.1.2 Calculation of ANOVA Tables

Calculation of the ANOVA Tables for the experimental evidence is a standard method to be found in such books as Snedecor (1946) and Huitson (1966) and will not be discussed here.

The purpose of this section is to show how the ANOVA Tables may be derived for the actual evidence to compare with the experimental results.

For each one of the nine original Tables of Classification in the actual data an ANOVA Table may be calculated. The overall format is shown in Figure 5.3 which specifically details the categories chosen and extends the example illustrated in Figure 5.2.

FIGURE 5.3 FORMAT OF ANOVA TABLES FOR ACTUAL DATA
CLASSIFIED BY N GROUP AND YEAR

N GROUP	1974/76	1975/77	1976/78
Below 150 Kg/ha N	x(11)	x(12)	x(13)
Between 150-225 Kg/ha N	x(21)	x(22)	x(23)
Between 225-300 Kg/ha N	x(31)	x(32)	x(33)

Each x(ij) is an ANOVA Table based on data for each N group and for each pair of years within 1974/76, 75/77, 76/78. Recall that once these two classifications are defined that the farm observations are automatically given. As mentioned, the total number of observations used was 346 and these are categorised in each ANOVA Table as shown in Table 5.2.

TABLE 5.2 TABLE BY TABLE OBSERVATION FOR ACTUAL DATA
ANOVA RESULTS

ANOVA Table for:	x(11)	x(12)	x(13)	x(21)	x(22)	x(23)	x(31)	x(32)	x(33)
No. of observations in each (max = 402)	22	70	88	24	38	54	12	14	24

Given the assumption that each (ij) ANOVA Table has been independently calculated (that is, variance estimates are unbiased and uncorrelated with one another) then their elements - sum of squares, means squares, degrees of freedom - may be added. The addition of the ANOVA Tables can either be across rows in Figure 5.3: e.g. x(11)+x(12)+x(13); or down columns: e.g. x(11)+x(21)+x(31). The former enables comparisons to be made with the experimental results and represents the primary motivation for the emphasis on these results to be

presented in Tables 5.5 - 5.7. The latter form enables analysis of through-the-years variance and is calculated to show the range of variability in output over the sample period.

For example, the addition of the ANOVA Tables to produce a framework to examine variations in N against farms and year of observation would take the form:

$$y(1) = x(11)+x(12)+x(13)$$

$$y(2) = x(21)+x(22)+x(23)$$

$$y(3) = x(31)+x(32)+x(33)$$

It should be clear that once this addition has taken place that further addition would be superfluous to the analysis. Thus, to perform the addition $z=y(1)+y(2)+y(3)$ would preclude comparison with the experimental results because it completely masks variation subject to N input. One element of variation must therefore be omitted to give meaning to the other two because controlled estimates of variation do not exist.

5.4.2 Regression

The results of the ANOVA section are extended in a regression framework. Only actual data is analysed since there is insufficient variation in experimental N input to support coefficient estimates. The analysis also enables us to indicate the direction of influence of N on grassland output risk. Moreover, further information is provided concerning the relationships between the entire range of N used (0-300 Kg/ha). Because we use ANOVA methods, within-group variation of N is essentially orthogonal to the use of between-group comparisons hence investigation by regression methods provides parameter estimates which are pertinent to all the data, and all the N used.

5.4.2.1 Method

The hypothesised relationship is that risk arising from variations in grassland output (UME) is related to the level of rainfall and the amount of N used. It is well known that rainfall facilitates movement of N in the soil thereby increasing its effectiveness. We investigate how N-effectiveness influences risk where risk is defined as a standard error of output. The standard error is calculated over the two observations relating to the two harvest years in any one of the periods 1974/76, 75/77 or 76/78. That is, a series of standard errors are calculated which we then assume to be a series of observations on risk. Risk calculated in this manner is hereafter referred to as 'absolute' risk, or the 'absolute standard error'. We also calculate proportional standard errors to represent risk as it relates to different levels of N: that is, yields proportional to the amount of N used. The first measure is used to show what is actually happening to the data and the second is used to show the data-interrelationships through varying N levels.

The standard errors are derived in the following manner. Recall that for each farm in the actual data there is a pair of UME output observations for each of the recording periods 1974/76, 1975/77 and 1976/78. Thus, for example, in the recording period 1974/76 there is a figure for UME output for the harvest year 1974/75 and another for the harvest year 1975/76. Out of this pair of UME observations a standard error is derived. The standard error is therefore based on two observations only and may consequently lack the statistical rigour that is usually required. However, in order to derive a series of observations on risk (standard errors) we must assume that the sample standard errors so derived reflect their population counterparts. For any particular farm in any one of the recording periods (1974/76, 1975/77 or 1976/78) an absolute and proportional standard error is formed. Let X_1 be the observation on UME output for, say, the harvest year 1974/75 in the recording period 1974/76 and X_2 be the UME observation for the harvest year 1975/76 in the same recording period.

The absolute standard error for any one farm in the recording period 1974/76 is equal to:-

$$\sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2}{n-1}} = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2}{1}}$$

This is equivalent to:-

$$\sqrt{\left[X_1 - \frac{X_1 + X_2}{2}\right]^2 + \left[X_2 - \frac{X_1 + X_2}{2}\right]^2}$$

Now

$$\left[X_1 - \frac{X_1 + X_2}{2}\right]^2 = \left[\frac{2X_1 - X_1 - X_2}{2}\right]^2 = \left[\frac{X_1 - X_2}{2}\right]^2$$

and

$$\left[X_2 - \frac{X_1 + X_2}{2}\right]^2 = \left[\frac{2X_2 - X_1 - X_2}{2}\right]^2 = \left[\frac{X_2 - X_1}{2}\right]^2$$

Therefore

$$\begin{aligned} &\sqrt{\left[X_1 - \frac{X_1 + X_2}{2}\right]^2 + \left[X_2 - \frac{X_1 + X_2}{2}\right]^2} = \\ &= \sqrt{\left[\frac{X_1 - X_2}{2}\right]^2 + \left[\frac{X_2 - X_1}{2}\right]^2} = \sqrt{2 \left[\frac{X_1 - X_2}{2}\right]^2} = \sqrt{\frac{[(X_1 - X_2)^2]}{2}} \end{aligned}$$

The proportional standard error is simply derived by analogy and is equal to (in relation to the case above):-

$$\frac{\sqrt{[(X_1 - X_2)^2]}}{2K}$$

where, for this example only, $K = N$ input.

In this way we can generate a series of standard errors which represent variability (risk) on a per farm basis. Absolute and proportional standard errors are calculated for all farms for which a pairing (that is, differencing for the dependent variable - see below) could be defined through all the years available for investigation, viz. 1974/76 - 1976/78. In that sense, we essentially pool the cross-sectional (observations in any one pair of years) and time series data (observations through pairs of years) to establish a data set on which the regression results are based.

We then categorise risk on the basis of the average amount of N used (average of the two observations on the harvest years in the three pairs of years).

They are:

- 1) Group 1: average N input of 150-225 Kg/ha
- 2) Group 2: average N input of 225-300 Kg/ha

which are the Groups referred to in Sec. 5.2.

Since the purpose of the investigation is to examine how the intensification of grazing - as represented by increased output arising from greater N input - affects risk we form a variable of the difference in standard errors between the lower N Group users (Group 1) and the higher level users (Group 2). The pairing of one standard error of UME output with another to form the difference is done on a purely random basis hence this precludes any statistical discrepancy arising from observations which are in close geographical proximity to one another.

The dependent variable then represents variability (risk) in UME output in the two N groups (Groups 1 and 2). Group 1 standard errors measure variability of UME in the N range 150-225 kg/ha; Group 2 standard errors measure variability in the N range 225-300 kg/ha. These ranges roughly correspond to the set levels of 150 kg/ha N and 300 kg/ha N that have been analysed in the experimental

results. It is then clear why the regression analysis provides additional information with respect to risk over and above the experimental evidence. The actual data enables analysis of risk over varying N levels, and the differenced dependent variable facilitates examination of the effects of rainfall and N input between lower N and higher N users. This was precisely the analysis of the experimental results but at set levels of N.

By creating a differenced dependent variable we attempt to establish how N and rainfall influences risk associated with different levels of N input: that is, representing intensification of grazing. This objective is approached by analysis of the coefficients (see Sec. 5.4.2.2) and observing the direction of influence from N and rainfall levels to risk.

The analysis presented specifically refers to dairy farms although we would expect the conclusions to be drawn to be relevant to other grazing stock.

5.4.2.2 Analysis of the Signs of the Coefficient Estimates.

The equations to be estimated take the form

$$RDA = a_0 + a_1 N1 + a_2 N2 + a_3 R1 + a_4 R2 \quad (5.1)$$

$$RDP = b_0 + b_1 N1 + b_2 N2 + b_3 R1 + b_4 R2 \quad (5.2)$$

Where $RDA = AABSE1 - AABSE2$ and $RDP = APRSE1 - APRSE2$.

Given the nature of the dependent variable it was thought worthwhile to estimate differences in N and rainfall levels; viz.

$$RDA = c_0 + c_1 (N1-N2) + c_2 (R1-R2) \quad (5.3)$$

$$RDP = d_0 + d_1 (N1-N2) + d_2 (R1-R2) \quad (5.4)$$

In essence, therefore, each equation (5.1-5.4) is a combination of two equations: one relating to Group 1 N users, and another relating to Group 2 N users. For example, we could analyse the inherent combination of equations in equation 5.1 as

$$\begin{aligned} \text{AABSE1} &= e_0 + e_1 N1 + e_2 R1 \\ \text{AABSE2} &= f_0 + f_1 N2 + f_2 R2 \end{aligned}$$

But the differenced dependent variable is used (equation 5.1) because it enables examination of how the explanatory variables (N1 , N2 , R1 , R2) react with changes in variability in UME output. Furthermore, because the Groups 1 and 2 N ranges correspond with the experimental set levels then a rough comparison of the results may be attempted. This is seen in terms of the following discussion. Second-order interaction variances were calculated in the ANOVA results, such as N by F, Y by F and N by Y. This estimates variation in grassland output attributable to combinations of N, F and Y. What it cannot do, however, is to examine variability in grassland output over a range of N levels: in terms of the second-order interaction terms this would be N by N. Regression analysis does this and the differenced dependent variable is one way in which this objective may be achieved.

A priori reasoning on the signs of the coefficients suggests that they will follow the sign of that part of the dependent variable to which they mostly relate. For example, N1 is clearly related to AABSE1 (for the latter is defined on the basis of the former). If there is an expected negative relationship then a_1 in equation 1 will be negative. If the same relationship holds between N2 and AABSE2, then a_2 in equation 1 will be positive because of the effect of the negative sign on the variable AABSE2. This reasoning holds for all equations estimated.

The coefficients in equations 5.3 and 5.4 are slightly more complicated although the reasoning above still basically applies. First and foremost the degree of common variation between the differenced independent variable and the dependent variable is the important determinant of coefficient signs. But secondly, the sign of the coefficients will depend on which N and rainfall group is the most pervasive in practice; that is, the working environment. If, for example, N input associated with N1 group is a more common feature in practice than is N2, then $\hat{c}_1$ in equation 3 is likely to be negative if there is an expected negative relationship between N1 and the dependent variable.

An additional problem arises if N1 dampens variations in AABSE1 or APRSE1 whilst N2 increases it in AABSE2 or APRSE2. This is improbable but conceivable. In this case the coefficients c_1 and d_1 in equations 5.3 and 5.4 will be negative but the influences of the two N groups, although fundamentally differing in their effects on variation, are mutually supportive in determining the sign of the coefficients.

Weighted regression procedures are used in the analysis where the object is to isolate the effects of soil condition and the existence of (relative) drought from the other aspects of the investigation. Indices are defined for the drainage capability of the soil (taken to represent its condition) and the influence of drought. The definitions of these has already been given in section 5.2.

5.5 Results and Analysis

5.5.1 ANOVA Results

Experimental evidence is presented in Tables 5.3 and 5.4; actual evidence is presented in Tables 5.5 - 5.10. The presentation format follows the discussion of their theoretical derivation.

TABLE 5.3 ANOVA. EXPERIMENTAL EVIDENCE. PATTERN 1

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year (Y)	3	13.8835	4.6278	26.66
Nitrogen (N)	1	435.4402	435.4402	258.63
Farm (F)	20	478.6237	23.9316	60.63
Y by N	3	0.5908	0.1969	5.44
Y by F	60	162.1758	2.7029	20.37
N by F	20	25.9386	1.2969	14.11
Y by N by F	60	15.4699	0.2578	6.29
TOTAL	167	1132.1315		

GRAND MEAN OF DATA 8.07

TABLE 5.4 ANOVA. EXPERIMENTAL EVIDENCE. PATTERN 2

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year (Y)	3	11.0855	3.6952	23.38
Nitrogen (N)	1	389.1511	389.1511	239.89
Farm (F)	20	457.9593	22.8980	58.19
Y by N	3	0.0809	0.0270	2.00
Y by F	60	142.7867	2.3798	18.76
N by F	20	15.2049	0.7603	10.61
Y by N by F	60	15.1216	0.2520	6.10
TOTAL	167	1031.3900		

GRAND MEAN OF DATA 8.22

The first-order effects for both Patterns 1 and 2 in Tables 5.3 and 5.4 suggests that a significant amount of variability exists under experimental conditions.

Variability in Dry Matter Yield associated with N is quite large although the figure has to be interpreted with care. All that can be said about it is that it is a 'statement of fact'. That is, N fertilisation is set at definite levels (150 and 300 kg/ha) and the response of grass is fairly predictable from that fact alone. What gives it meaning in relation to risk is when it is related to the really variable influences in the results: differences due to year and farm observations. These are variable because they are different: N input is the same through all years and across all sites (for each experimental plot) and cannot therefore have any implication for risk as it stands. The real measures of uncertainty or risk are the differing soil and climatic conditions inherent in the farm and year first-order effects. These figures represent ambient risk. But when they are related to N input to form the respective second-order effects then we will obtain some idea how N fertilisation, at given levels, interacts with this inherent variability. That is the purpose of the exercise: not to examine risk associated with a set level of N input but to investigate how its application to the soil influences the real uncertainties that exist independently of its use - soil and weather variability.

The conclusion that the first-order variance figure for N in the experimental results is a 'statement of fact' should now be clear. What the figure does tell us is that there is significant response in terms of variation of grass to set levels of N input at 150 kg/ha and 300 kg/ha.

First-order effects on grassland output in relation to year and farm are perhaps more indicative of true variability (and hence risk) as they cannot be so strictly controlled as N input. Coefficients of variation of 26% (Year)

and 60% (Farm) in the Pattern 1 data suggests that variability occurs within years but that variability across farms (and therefore variability subject to local geographical conditions) is greater. No influence can be attributed to farm variability from differences in the abilities of the farmer concerning grassland management for that aspect of production was controlled in the experimental case. It will be a more important factor in relation to the actual data where farmer-ability is a variable feature. In both experimental and actual cases geographical location will be a major influence on output variability from farm to farm. For the experimental case farm sites ranged from Northumberland, West Wales, East Anglia, Kent and Devon. There is no clear indication about the spread of sites in the actual data cases although the sample was said to cover England & Wales.

Year to Year variability is a more general weather phenomenon for the experimental case but will include changing farming practices in the actual case. It is primarily year to year variation in grassland output that makes farm planning of feed sources such a difficult exercise for those utilising grazing resources. The evidence suggests that this is a significant feature of variation for the experimental case with little difference existing between mean squares for both Patterns of N application (4.63 and 3.69 for 1 and 2 respectively).

The interaction variances, or second-order effects, are the more important aspects of the analysis for the problem to be investigated; that is, what influence or relation, if any, does increased fertilisation by means of N have on grassland variability with respect to variability arising from the year of observation and from the farm location? Or, does increased N usage, as far as its effect can be isolated, contribute any extra variation to grassland output than that which already exists in terms of year and farm variation?

The experimental evidence suggests that it does not in relation to year by N variation although it may add more on a farm by farm basis. The differing result between the two interaction effects may be explained in terms of general and local weather conditions. In as much as 'average' weather prevails (where 'average' refers to a national average) then N application to the soil will not alter the inherent variability of output. Local weather conditions, as represented in the geographical spreads of the farm sites, are likely to have an important and significant interaction with N application as a response to different soils, swards and climates and this variability will be enhanced by differing interaction between these factors. Hence, very little in the way of general description of risk at the farm level can be said.

The year by N variation does suggest that the average response is zero, or that there is no systematic relationship between them. One possible reason for this is that extra N fertilisation may reduce yield variation at times and increase it at other times with the net effect cancelling out. In a situation of this kind it may ease the relative variability that the representative farmer may face as a result of changing growing conditions through the years at least within the range studied. In this respect, increased N application does not add extra variability and hence extra risk to the intensification of grazing.

Third-order interaction effects in both experimental cases suggest very little influence of one factor's variability with the other two. There is no way of telling from this figure alone which factor is influencing which although the two-factor interaction results will tentatively suggest how the result is composed (for instance, year by N variation will have much less of an influence than year by farm variation).

ANOVA. ACTUAL EVIDENCE. BY NITROGEN GROUPS

TABLE 5.5. BELOW 150 KG/HA N.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year	3	1003.7734	334.5911	42.83
Farm	87	17514.0550	201.3110	33.22
Dis(*)	87	4100.2266	47.1290	16.07
TOTAL	177	22618.0550		

GRAND MEAN OF DATA 42.71

* Discrepancy: Can be roughly understood as Year by Farm variation. More details below.

TABLE 5.6. BETWEEN 150-225 KG/HA N.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year	3	2033.3964	667.7988	52.04
Farm	55	9961.5110	181.1184	27.10
Dis	55	4746.6036	86.3015	18.71
TOTAL	113	16741.5110		

GRAND MEAN OF DATA 49.66

TABLE 5.7. BETWEEN 225-300 KG/HA N.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year	3	1511.6666	503.8889	44.81
Farm	22	3767.8570	171.2662	26.12
Dis	22	1584.8334	72.04	16.94
TOTAL	47	6864.3570		

GRAND MEAN OF DATA 50.09

ANOVA. ACTUAL EVIDENCE. ANALYSIS BY YEARS

TABLE 5.8. 1974-1976

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year across N	3	1512.3835	504.1278	41.88
Farm	26	5355.9130	205.9967	26.77
Dis	26	2134.1165	82.0814	16.89
TOTAL	55	9002.4130		
GRAND MEAN OF DATA 53.61				

TABLE 5.9. 1975-1977

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year across N	3	264.8454	88.2818	20.97
Farm	58	10536.1100	181.6571	30.08
Dis	58	3564.6546	61.4596	17.50
TOTAL	119	14365.6100		
GRAND MEAN OF DATA 44.81				

TABLE 5.10. 1976-1978

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Coefficient of Variation
Year across N	3	2771.6075	923.8692	69.02
Farm	80	15351.4000	191.9825	31.46
Dis	80	4732.8925	59.1612	17.47
TOTAL	163	22855.9000		
GRAND MEAN OF DATA 44.04				

The actual data ANOVA Tables have to be analysed with considerably greater caution since it is not a controlled environment that we examine. Tables 5.5 - 5.7 are investigated first to suggest a more direct comparison with the experimental results.

The results within Tables 5.5 - 5.7 represent two-way classifications defined over three different N ranges (Tables 5.8 - 5.10 are two-way classifications defined over three different pairs of years). An interaction term is calculated and presented in the results and is referred to as 'Dis'. This, however, cannot be directly attributable to year by farm variation because N input is not fixed absolutely (as in the experimental case) and because some of its effects are confounded with other sources of variation, unaccounted for. It is therefore more accurately described as 'discrepancy' although some degree of year by farm interaction may be inferred from the result. A similar reasoning holds for the results in Tables 5.8 - 5.10.

The most obvious feature of the results is the greater degree of variability in all instances. This is a consequence of the fact that observations are made on working farms where many influences will interact to produce the final results. It is therefore more difficult to isolate variances attributable to farm, year or N in relation to grassland output. For example, measures of variation are in terms of the digestive processes of cattle plus any measurement error in calculating UME.

First-order effects are large in all N classes for Tables 5.5 - 5.7. However, there is a definite increase in variability from below 150 kg/ha N to higher groups but this levels off thereafter. It would appear that significantly more N application is required under working conditions to offset undue variation attributable to farm and year variation alone. In fact, the figures in isolation would suggest that it is not worthwhile to invest in N fertilisation to intensify grazing for the coefficients of variation in output at higher

levels of N input are either greater or more or less the same than for those farmers that use less N. But to adopt a strategy of no fertilisation on the grounds that N fertilisation adds to variation alone would be wrong since its isolated effect, as demonstrated in the experimental results, is to leave output variation unchanged under average condition through the years.

In general, the analysis of the results does not suggest more than that the Coefficient of Variation associated with Year and Discrepancy remains constant as N rises. Moreover, there is some doubt as to whether the high levels of N application in the top range (223-300 Kg/ha) are contributing to extra yield or offsetting poorer natural fertility.

Tables 5.8 - 5.10 present further evidence on grassland response although the statistics do not reflect much more than through-the years variation.

N application cannot be isolated completely because of the way the original data is composed in terms of three pairs of years. Discrepancy in this instance is therefore another measure of year by farm variation although 'year' refers to within the two years comprising 1974/76, 1975/77 or 1976/78.

Overall variation is again much higher than in the experimental case and coefficients of variation are large in relation to the grand mean of the data. This suggests that output variation may be as much in any one year so as to either wipe-out or double average production. No wonder that farmers are risk-averse!

Some of the farms analysed for the earlier years in Tables 5.8 - 5.10 appear to have a higher yield which is not readily understandable in terms of the year effects: 1974/76 was not a good period for grassland productivity taking the country as a whole. The implication is that those farms that use more N for fertilisation were able to counter some of the more adverse effects of the severe droughts that were experienced at that time.

5.5.2 Regression Results

This section presents the results of the analysis of risk in actual setting where risk is measured in terms of standard errors of UME output.

TABLE 5.11 RESULTS OF REGRESSION ANALYSIS FOR ACTUAL DATA

Dependent Variable	Constant	N1	N2	R1	R2	N1-N2	R1-R2	$\bar{R}^2$	
RDA	-.0089 (2.149)	-.1513 (.062)	.0719 (.068)	.0076 (.011)	.0046 (.006)			.1057	(5.5)
RDA (DRA)	-.0426 (2.454)	-.1712 (.071)	.0869 (.076)	.0059 (.013)	.0059 (.006)			.1393	(5.6)
RDA (DRO)	.0688 (1.899)	-.1923 (.057)	.1157 (.067)	.0052 (.011)	.0041 (.006)			.1859	(5.7)
RDP	-.005 (.060)	-.003 (.002)	.0005 (.002)	.0005 (.002)	.0004 (.0001)			.2452	(5.8)
RDP (DRA)	-.0057 (.063)	-.0032 (.002)	.0006 (.002)	.0001 (.0004)	.0005 (.0001)			.3082	(5.9)
RDP (DRA)	-.0373 (.055)					-.0013 (.0009)	-.0003 (.0001)	.1445	(5.10)
RDP (DRO)	-.041 (.059)					-.0013 (.0009)	-.0003 (.0001)	.2080	(5.11)

Standard errors in parentheses. DRA and DRO are weighted regressions explained in Sec. 5.4.2.2. All standard errors corrected for the existence of autocorrelation when present. Sample size = 42.

The sample size in the regression analysis requires some explanation. It was previously mentioned in Sec. 5.4.2.1 that the data set used for the regression analysis was pooled cross-sectional and time series. This produced a total potential data set of 346 observations which was the figure used in the actual data ANOVA investigation. The individual groups of observations for each $x(ij)$ ANOVA Table of Classification that comprised the main results (Tables 5.5 - 5.10) were presented in Table 5.2. In the regression analysis we use only those

observations which fall in either one of the N groups 150 - 225 Kg/ha or 225 - 300 Kg/ha; hence Tables of Classification x(11), x(12) and x(13) in figure 5.3 are irrelevant to the following discussion. Now, we have paired standard errors of UME observations on a random basis between low N-group users (Group 1) and high N-group users (Group 2). Thus, referring to the data in Table 5.2 the Table of Classification x(21) is paired with data in the Table of Classification x(31); and similarly for x(22) with x(32) and x(23) with x(33). It is clear that the maximum number of pairings can only be equal to the smaller number of observations in any one pair x(21) with x(31) and x(22) with x(32) and x(23) with x(33). Therefore, there are 12 pairs of observations in the Tables of Classification x(21) and x(31) because x(31) has only 12 observations. Similarly, the pairing of x(22) with x(32) produces 14 observations and the pairing of x(23) with x(33) produces 24 observations. This establishes a total of 50 observations available for regression analysis. However, it turned out that 4 of these observations are unusable because of zero standard errors of output as a result of equal UME output in each harvest year of the recording periods, and a further 4 were lost to keep the number of observations between recording periods equal. This then produces a maximum working sample of 42.

The most interesting item of note is the consistent sign of the coefficient on the variable N1 which is significantly negative in all of the equations in which it is represented. Recall that the dependent variables are differences in standard errors (proportional and absolute) of UME from dairy farms over the two N ranges chosen. The fact that N input in the range 150-225 Kg/ha has everywhere a strong negative influence suggests that:

- 1) lower N fertilisation levels are far more important in actual experience revealing perhaps the generally conservative attitude of farmers towards grassland management. But more importantly

- 2) that N fertilisation has a "calming" influence on the variation of grassland output (or more accurately, UME derived from grazing).
- 3) that farmers who use more N are more capable of using N or other techniques to reduce weather hazard.

It is clear that over both ranges of N input, and especially the lower, that the influence of the application of N is to reduce variability in output and that in a real and uncertain environment investment in N fertilisation reduces the risk associated with utilising the potential that grass has to offer as an alternative feeding source.

The positive sign of the higher N input variable (N2) suggests that variability will continue to fall but not as much after a certain level of N usage has been achieved. The alternation in signs between N1 and N2 has been previously explained and is due to the different signs of the component variables in the differenced dependent variable.

Consideration must also be given to the variable R2 (average rainfall associated with Group 2 data). The interpretation to be placed on the influence of this is that rainfall becomes a more significant factor in relation to variation in grass yield when higher levels of N input are used. This is determined by water circulation in the soil when N is applied. The prevailing view is that movement of N already in the soil due to the influence of rainfall is crucial for its full utilisation and hence becomes as important as the level of N itself. The two interact so as to facilitate greater fertilisation. The higher average rainfall appears to reduce the standard error in output associated with the higher N Group (AABSE2) and so allow heavier N fertilisation with less risk.

Equations 5.10 and 5.11 suggest further evidence as to the relative strength of response of grassland variability to different levels of N input and rainfall. The negative sign of the coefficient on the variable (N1-N2) indicates that lower levels of N are generally predominant. The negative sign of the coefficient on the variable (R1-R2) suggests that R2 has more of an effect on variation on grassland output from the explanation of the nature of the signs given in Sec. 5.4.2.2.

Although well reported elsewhere (ADAS/GRI (1980 a) and University of Exeter (1980)), the role of N fertilisation on the level of response of grass is investigated. Looking at the evidence in terms of absolute and proportional standard errors in Table 5.12 it is evident that N does not influence the level of either standard errors when represented by means of data except for absolute standard errors in the experimental case (EABSE1 cf. EABSE2). It can therefore be safely presumed that the risk associated with output variation from grass will not increase under normal conditions (as opposed to experimental conditions). It is significant that the interrelationships of grass output and varying N levels represented by proportional standard errors do not have different means. In this sense one will not be worse-off by using more N as a fertiliser since proportionately one will be in the same position as far as risk is concerned: that is, risk is constant as a proportion of UME output over different N levels.

TABLE 5.12. F-TESTS ON MEANS OF ABSOLUTE AND PROPORTIONAL STANDARD ERRORS

Comparing the means of:	Result	
AABSE1 c.f. AABSE2	H0	H0 = means of each group equal
APRSE1 c.f. APRSE2	H0	H1 = means of each group unequal
EABSE1 c.f. EABSE2	H1	
EPRSE1 c.f. EPRSE2	H0	

5.6 Conclusions

The relevance of uncertainty to agricultural efficiency cannot be denied when moving away from the theoretical environment. The statistical analysis of this chapter confirms that the variance of yields is substantial especially when estimated from the residual method (that is, we define risk as 'variation').

What we did not find was evidence that risk rose as N fertilisation increased, especially when considering the Coefficient of Variation as a measure of risk. While we cannot be certain that we have held constant all factors contributing to variation other than N levels, we consider it probable that any link between high N use and higher risk must be offset by other links reducing risk at higher N levels; either because other sources of variation are suppressed (this would appear the logical line of argument in considering experimental data) or because of altered management techniques (a possibility when actual evidence is considered).

The conclusion is apparent: there is no 'grazing problem' attributable to the intensification of grazing resources by increased use of N. The risk that already exists is mainly a product of local weather and other geographical conditions compounded with variations in these factors over the years. It is this aspect of variation to which farmers are averse and leads to the under-utilisation of grazing resources. The results of this chapter represent the position of nitrogen fertilisation with respect to grass production in general (ADAS/GRI 1980 a) and to grazing on dairy farms (ADAS/GRI 1980 b). Whilst the results are only specifically relevant to these it is felt that the conclusions drawn are more general and that they have implications for the livestock markets that are studied in the following chapters.

RISK, ADAPTIVE EXPECTATIONS AND THE ESTIMATION OF STORE LIVESTOCK DEMAND

6.1 Introduction

The demand for store livestock in the beef, dairy, pigs and sheep markets is examined. It will be seen how expectations and risk enter as important elements into the store purchasing decision process. Crucial aspects of the analysis to be fully investigated are the mathematical and econometric approaches to providing optimal and unbiased estimates of the processed data that enter as expectations variables in the equations, and define the estimates of risk.

6.2 Variable Definitions and Data

Definitions of variables used in this chapter are

SC_t	=	Actual Store Price
FT_t	=	Actual Fatstock Price
FD_t	=	Actual Feedgrain Price
DC_t	=	Actual Dairy Cow Price
FT^*_{1t}	=	Expected Fatstock Price
FD^*_{2t}	=	Expected Feedgrain Price
DC^*_{3t}	=	Expected Dairy Cow Price
R^*_{1t}	=	Expected Risk on Fatstock Price
R^*_{2t}	=	Expected Risk on Feedgrain Price
R^*_{3t}	=	Expected Risk on Dairy Cow Price
COV^*_{12t}	=	Expected Covariance Risk between Fatstock and Feedgrain Price
COV^*_{13t}	=	Expected Covariance Risk between Fatstock and Dairy Cow Price
COV^*_{23t}	=	Expected Covariance Risk between Feedgrain and Dairy Cow Price
LN_t	=	Total Livestock Numbers
HAY	=	Hay Price

This is a format in which all variables will be presented in the subsequent results. They should be understood in context: that is, when SC_t appears in an equation representing the pig market then it should be taken as the store pig price; when SC_t appears in the equation representing the sheep market then it should be taken as the store sheep price, and likewise for other symbols. Variables which have an asterisk superscript are expectations. All expectations in this Chapter are made for period t based on information available up until the end of period $t-1$ (See Sec. 2.4.1). Subscripts 1, 2 and 3 for risk variables indicate to which expected price they are attached. Thus R_{1t}^* is the expected risk associated with FT_{1t}^* .

Definitions to the variables in terms of the data is outlined in Appendix 6.

6.3 Expectations Generation and the Definition of Risk

To enable comparisons with other work using the Adaptive Expectations (AE) hypothesis along with other backward-looking mechanisms which define risk (Sec. 2.4.2) we use I_{t-1} as the base-period information set. An expectation is then required for any variable with a time subscript greater than $t-1$; for example, X_t must then be written as $E(X_t/I_{t-1})$ should it be required as a decision variable at time $t-1$. The precise meaning of base-period information sets in relation to expectations formation has been discussed in Sec. 2.3.1.

The meaning of $E(X_t/I_{t-1})$ in the context of the Adaptive Expectations approach must be qualified. We discussed in Sec. 2.4.2 exactly what the AE hypothesis implies in terms of geometrically weighting past actual observations of the variable to be predicted. The information set I_{t-1} in an AE framework is therefore composed of past actual values of the prediction-variable. I_{t-1} should not be taken as implying that the AE hypothesis uses all the available

information, for we have seen from the discussion of Rational Expectations in Sec. 2.4.3 that it does not. When we speak of I_{t-1} in this Chapter it is implicit in the argument that account is taken of this caveat.

The influence of subjective risk on purchasing decisions in the Store Livestock markets is examined. It is accepted that expectations play an important role in decision-making but we must also accept a potential role for the risk of misestimating these expectations. The variance measure of risk is used (Sec. 4.2.1) where the 'deviation' now refers to the difference in the actual value of the variable in question from its expected value; that is: taking any of the expected values (FT_{1t}^* , FD_{2t}^* , etc.) as X :-

$$(X - E(X))$$

and variance for decision making purposes is defined as

$$E\{(X - E(X))^2\}$$

The entire investigation of the expectations hypothesis then rests on how the expected variable $E(X)$ is defined.

6.4 Model Formulation

Five store demand equations are estimated: one each for beef steers, beef heifers, dairy, pigs and sheep. With the exception of the dairy model the equation to be estimated takes the general form:

$$SC_t = g(SC_{t-1}, FT_{1t}^*, FD_{2t}^*, R_{1t}^*, R_{2t}^*, COV_{12t}^*, LN_{t-1}, HAY_t) \quad (6.1)$$

The expectations variables in equation 6.1 represent the expected profitability in relation to feed costs and final fatstock sale value of the marginal animals plus an account of the attendant risks. We are not concerned with physical risks on, say, the proportion of animals that may perish in the course of their time on the feeding farm as a consequence of disease or other hazard. Consequently, the expected profitability risk for the marginal animal is, in principle, identifiable because there cannot be a proportion of a single animal which perishes. In other words, this particular physical risk is unlikely to be a consideration when the farmer decides to purchase the marginal store.

We assume that equation 6.1 models the store purchasing decision process in the region of equilibrium. The motivation for the use of prices alone in the equation as representing profitability was explained in Sec. 4.3.1. To reiterate briefly; since we investigate the reasons why a single store animal is purchased, the specification of a production function is not required in order to define profitability, which simply becomes equivalent to price on a unit basis. The combination of sale (FT_{1t}^*) and cost (FD_{2t}^*) prices defines profitability, and their associated risks (R_{1t}^* , R_{2t}^* , COV_{12t}^*) accounts for the misestimation of expected prices, or accounts for their expected variability. Store purchasing will then continue up to the point where expected profitability becomes an inadequate cover of the expected risks involved and no longer provides a sufficient margin over the buying-in price (SC).

A risk of misestimating expectations must accompany every expected variable. Furthermore, we cannot rule-out, a priori, any relationship between expected fatstock and feed prices hence the possibility of a covariance of any two risks must be accepted. This is seen from the following general discussion. For any two related variables the variance of their difference is equal to

$$\text{Var}(X-Y) = \text{Var}(X) + \text{Var}(Y) - 2.\text{Cov}(X,Y) \quad (6.2)$$

If X and Y are expected fatstock and feed prices, respectively, then to define the exact relationship between them all we have to do is to load this difference by adding the coefficient 'weights' to account for differing units of measurement. Thus let

$$z = \beta_1 FT_{1t}^* + \beta_2 FD_{2t}^*$$

$$\text{then } \text{Var}(z) = \beta_1^2 \text{Var}(FT_{1t}^*) + \beta_2^2 \text{Var}(FD_{2t}^*) - 2\beta_1\beta_2 \text{Cov}(FT_{1t}^*, FD_{2t}^*)$$

where the expected sign of β_2 is negative.

The only difference between this discussion and our own use of the equation 6.2 is that we specifically define variance and covariance to be

$$\text{Var}(FT_{1t}^*) = E\{(FT_{1t} - FT_{1t}^*)^2\}$$

$$\text{Var}(FD_{2t}^*) = E\{(FD_{2t} - FD_{2t}^*)^2\}$$

$$\text{Cov}(FT_{1t}^*, FD_{2t}^*) = E\{(FT_{1t} - FT_{1t}^*)(FD_{2t} - FD_{2t}^*)\}$$

It has already been seen that these measures represent 'moving risk' where the validity of the result is based on the most general definition of variance (Koutsoyiannis 1977 pg. 534).

The pressure of store demand is reflected in the market price (SC) which is used throughout this chapter as the dependent variable. Thus, when we speak of the store demand results in Tables 6.3 - 6.7 it should be taken to mean store demand as reflected in store price, not on the quantity of stores demanded.

Lagged store price is used in some cases (where its inclusion improves results) as a measure of partial adjustment of response of store demand to

changing market conditions. Under no circumstance should this be confused with the adaptive expectations hypothesis that is used to define expectations and risk variables. It is accepted that a lagged dependent variable is frequently used to define adaptive expectations as we have used it for illustrative purposes in Sec. 2.3.1. The expectations mechanism used in this chapter is specified by a two-step estimation procedure and uniquely defines the role of expectations when they are generated and subsequently used in the store demand equation 6.1. There is then no theoretical justification for using a lagged dependent variable to test expectations hypotheses. The distinction will become clearer when the econometric procedure is examined. What we do wish to capture by the use of a lagged dependent variable is sluggish adjustment as a consequence of prohibitive costs to change, or bottlenecks in production, or as an indication of supply of stores onto the market in previous periods.

A pseudo-reduced form is therefore estimated where lagged livestock numbers plot how the potential entrants onto the store market determine the store purchasing decision. This variable is either used in addition to the lagged dependent variable or as an alternative variable if warranted by the results.

Finally, the price of Hay is used in the equations for ruminant stock and reflects a shadow price of grazing availability. That is, should its price rise then it is taken to mean a general shortage of grass, fodder and other natural feeding sources grown on the farm which may enter the production processes of most farms.

The corresponding equation for the Dairy Market takes the form

$$SC_t = h(SC_{t-1}, FT_{1t}^*, FD_{2t}^*, DC_{3t}^*, R_{1t}^*, R_{2t}^*, R_{3t}^*, COV_{12t}^*, COV_{13t}^*, COV_{23t}^*, LN_{t-1}, HAY_t) \quad (6.3)$$

The equation is complicated by the fact that when a dairy cow is taken out of the herd it can either be sold as beef in which case FT_{1t}^* is the appropriate measure of sale income, or it can be sold into another dairy herd in which case DC_{3t}^* is relevant. The underlying lag structures specifying when these transactions take place in relation to the date at which the store was purchased in this equation and equation 6.1 will be discussed in Sec. 6.5.3 after the econometric procedure has been examined.

Associated with each expectation is a risk variable and associated with any two risk variables is their covariation.

To sum up, the aim is to show how expected profitability affects store purchasing decisions as reflected in the store price, taking into account any potential risk that may arise (that is, account for the 'risk premium' Ch. 2) and to consider what supply-side influences may be important.

6.5 Analytical Methods

This section deals with the difficulty of defining values for the unobservable variables (expectations) in equations 6.1 and 6.3. It is by no means a straightforward exercise and has been the subject of a vast amount of research over the past fifty years (c.f. Fisher 1930). We establish a strategy by which expectations for the unobservable variables including unobservable risk may be defined in an optimising framework by a two-step estimation procedure.

6.5.1 The Two-Step Estimation Procedure

The procedure can be represented as

- 1) generate expectations for unobservable variables including risk on the basis of an optimising procedure
- 2) insert the generated values into the main equations 6.1 and 6.3 and estimate by a standard method (OLS, ML)

The generation of all expected variables is based on the Adaptive Expectations (AE) hypothesis examined in Sec. 2.3.2. It is specified in its most general form without explicitly defining a lag structure, because we shall subsequently see how this particular aspect of the hypothesis requires careful consideration:

$$X_t^* = X_{t-i}^* + \gamma (X_{t-i} - X_{t-i}^*) \quad (6.4)$$

The lag period, $t-i$, over which expectations are formed is usually set as if $i = 1$, but this so obviously depends on the frequency of data observations that its true implications are often overlooked. We have to specify exactly the period over which expectations are to be made in relation to the data available (e.g. quarterly, annual, etc.). If, for example, we were concerned with planting decisions and quarterly price predictions are required from equation 6.4 of a crop that takes one year to grow then the lag $t-i$ in 6.4 will be set at $t-4$. This will be called the P/E ratio to indicate exactly what lag structure we are using. Thus, $P/E=4$ for the quarterly price predictions of the annually produced crop. In all the results to be presented quarterly data is used and this should be recalled as we subsequently refer to P/E.

What purpose does this mechanism serve? It is precisely this: if we wish to make quarterly predictions of a process that takes one year to undertake then instead of specifying a four quarter lag on expectation and risk in the main equation to which the expectation and risk is to be inserted (in our case 6.1 and 6.3), we can set a four-quarter lag on the basis of the AE hypothesis (equation 6.4) and generate quarterly predictions. This precludes the requirement of lag structures in the main equation. When these estimates of expectations are inserted into the main equation we shall know that they have been estimated in such a way as to make quarterly estimates meaningful. By using this we do not complicate the main equations with lag structures; but more importantly, we ease the difficulties with which the expectations and risk variables may be inserted into the equation, because if a lag occurs on an

expectation variable then it must also appear on its associated risk and covariance in order for the latter to accurately relate to the former.

With the complicated biological lag structures involved in the store markets, and especially in the dairy sector (Ch. 2), this eases some difficulties with the lag specification of risk. It is particularly important in the covariance measures when inherently different lag structures may be involved. For instance, in the dairy equation 6.3 we will specify a six-quarter lag on expected dairy cow price and a two-quarter lag on expected fat cow price (Sec. 6.5.3). Specifying the lag on dairy cow risk and fat cow risk is easy enough since they simply follow their 'parent' measures (that is, six and two). But what of covariance risk between them? Should the lag be six quarters or two? It cannot be both. We shall show in this section how this particular problem may be overcome and how the two-step estimation procedure employing the P/E ratio lags in the AE hypothesis can be used to generate covariance risk.

To generate expectations the AE hypothesis is used as indicated in equation 6.4. However, we extend the analysis somewhat by incorporating a trend element into the equation. Our sample period of 1970-1980 is a particularly significant one with respect to the long-term movement in some prices. We have noted in Chapter 3 that fatstock and milk prices are partly determined by official policy, and that the accession of the UK to the ECC in 1973 is likely to have produced a greater air of confidence for producers because of the adjustment of British prices to higher European prices. This may have produced a long-term upward movement in prices because of the transitional phasing-in of the CAP. Consequently, this is likely to have affected expectations so as to establish a trend in their movement. This is on top of inflationary and seasonal movements which have been accounted for by appropriate transformations of the data (Appendix 6). Our approach is to specify the trend term in the AE hypothesis (equation 6.4) as a movement in

the difference of expected prices. Thus we augment the equation with the trend term and use $P/E=1$ for illustrative purposes which gives

$$X_t^* = X_{t-1}^* + \gamma (X_{t-1} - X_{t-1}^*) + \Delta X_t^* \quad (6.5)$$

where ΔX_t^* is the trend term.

The variable ΔX_t^* is an expectation. Its value is therefore unknown until an equation is specified for it in terms of observable variables. It is important that the logical mistake that

$$\Delta X_t^* = X_t^* - X_{t-1}^*$$

should not be made for that leaves the trend and expectations hypothesis redundant. This is easily established

$$X_t^* = X_{t-1}^* + \gamma (X_{t-1} - X_{t-1}^*) + X_t^* - X_{t-1}^*$$

$$X_t^* - X_{t-1}^* = X_t^* - X_{t-1}^* + \gamma (X_{t-1} - X_{t-1}^*)$$

$$0 = \gamma (X_{t-1} - X_{t-1}^*)$$

which proves that perfect foresight is the only solution consistent with setting $\Delta X_t^* = X_t^* - X_{t-1}^*$. We are not concerned with perfect foresight because that would leave all expectations hypotheses redundant on a priori grounds. Thus the difference operator, Δ , can only be used on the expectation term when we have defined an observable equivalent for expectations. The expected trend term is specified as an additional AE hypothesis with its own adjustment parameter, viz.

$$\Delta X_t^* = \Delta X_{t-1}^* + \epsilon (\Delta X_{t-1} - \Delta X_{t-1}^*) \quad (6.6)$$

The two equations 6.5 and 6.6 then complete the AE expectations hypothesis.

We have stated that the first step of the two-step estimation procedure is to generate expectations on the basis of an optimising procedure. The adopted method is to use the two equations (6.5 and 6.6) and find the mix of adjustment parameters (gamma and epsilon) that minimise the sum of squared errors between the actual value of X (however defined) and its expected value written in observable terms. This clearly defines a process which will minimise the inaccuracy with which expectations are formed. It will also minimise the scale of risk but it cannot, by itself, affect the way in which risk is perceived. That aspect depends on risk preferences (Sec. 2.2.2) and will be measured as a coefficient in the main equations 6.1 and 6.3.

We are now in a position to mathematically illustrate our discussion and give some precision to our analytical methods.

The minimisation objective is simply the Least Squares principle, hence all we need to do to perform our task is to rearrange our equations 6.5 and 6.6 so as to provide estimates of gamma and epsilon which simultaneously satisfy the principle. The adopted procedure is to develop a grid search over the likely bounds of gamma and epsilon and choose the minimum sum of squares.

Their bounds are likely to lie in the region of zero and unity (Nerlove 1958). The a priori expectation is that the direct effect of expectation in the level of movements in the variables as measured by gamma will be larger than any trend effect as measured by epsilon. This is because shorter-term fluctuations in variables are probably more important in providing shorter-term predictions (we shall use one-quarter predictions throughout) than the longer-term frequency with which trends are associated (ten years in our case: 1970-1980).

Let us consider equation 6.5 by itself for the time being. We shall substitute in the lag operator defined as $X_{t-n} = L^n X_t$ to simplify our analysis. The object of the exercise is to establish an equation of the expected value of

X in terms of observables only. Equation 6.5 can be re-written as:

$$X_t^* = LX_t^* + \gamma LX_t - \gamma LX_t^* + \Delta X_t^*$$

Collecting terms in expectations (and ignoring the trend term)

$$X_t^* (1 - L + \gamma L) = \gamma LX_t + \Delta X_t^*$$

$$\Rightarrow X_t^* = \frac{\gamma LX_t}{1 - \gamma' L} + \frac{\Delta X_t^*}{1 - \gamma' L} \quad (6.7)$$

where $\gamma' \equiv 1 - \gamma$

By analogy with equation 6.7 we can re-write equation 6.6 as

$$\Delta X_t^* = \frac{\epsilon L \Delta X_t}{1 - \epsilon' L} \quad (6.8)$$

where $\epsilon' \equiv 1 - \epsilon$

Since ΔX_t^* has been specified in terms of observables only we can now use the difference operator without committing the logical error mentioned (by setting $\Delta X_t^* = X_t^* - X_{t-1}^*$). Thus in terms of the lag operator, L, the difference operator, Δ , can be written as

$$\Delta \equiv 1 - L$$

Incorporating this into equation 6.8 and then substituting the result into equation 6.7 we have

$$X_t^* = \frac{\gamma L X_t}{1 - \gamma' L} + \frac{\epsilon(1 - L) L X_t}{(1 - \gamma' L)(1 - \epsilon' L)}$$

Rearranging further:

$$X_t^* = \left[\frac{\gamma(1 - \epsilon' L)L + \epsilon(1 - L)L}{(1 - \gamma' L)(1 - \epsilon' L)} \right] X_t$$

which is simplified in terms of standard notation as

$$X_t^* = \frac{A(L)}{B(L)} X_t \quad (6.9)$$

where $A(L)$ and $B(L)$ are polynomials in the lag operator, L , and are equal to

$$A(L) = (\gamma + \epsilon)L - (\epsilon + \gamma\epsilon')L$$

$$B(L) = 1 - (\gamma' + \epsilon')L + \gamma'\epsilon' L^2$$

Equation 6.9 is the basis of the grid-search iterative scheme. It requires further modification, however, to become operational for the LHS is still unobservable. The solution proposed is to define an equilibrium condition and set $X_t^* = X_t$ and so estimate gamma and epsilon on these grounds. This is intuitively reasonable since to define gamma and epsilon on the basis of anything else would be to derive solutions which are in a permanent state of disequilibrium, even in a stable period. We know that the equilibrium

condition to accord with the reasoning behind the AE hypothesis, for it is the purpose of the adjustment coefficients to adjust expectations to equilibrium, not to anything else.

However, let us remain with the notation of equation 6.9 for the time-being. We will return to the equilibrium condition later.

Our primary objective is to determine optimal values for gamma and epsilon and so determine optimal expectations. We need to re-specify equation 6.9 for estimation purposes. The equation, as it stands, is fairly complicated but iterative schemes exist whereby unique parameter estimates may be derived (unique in the sense of having a clear economic meaning). From equation 6.9 define:

$$X_t^+ = B(L)^{-1}X_t \quad (6.10)$$

so that

$$X_t^* = A(L) X_t^+$$

As with many mathematical and econometric procedures we have to deviate from the problem in order to solve it. The new problem is to define values for X_t^+ . Values for X_t^+ are unknown because it can be seen that the equation 6.10 is merely a function of unknown lagged values of itself:

$$X_t^+ = B(L)^{-1}X_t = X_t + (\gamma' + \epsilon')X_{t-1}^+ - \gamma'\epsilon'X_{t-2}^+ \quad (6.11)$$

This is not really an equation but an iteration. That is, we can 'start the ball rolling' by guessing at initial starting estimates for X_{t-i}^+ (for any pre-specified starting point, say $t-i < 0$) and generate successive values of X_{t-i}^+ ($t-i < 0$). Recall that the values of gamma and epsilon are also unknown so that we can perform a grid-search on the parameters so that initial estimates of these are set, and then re-set until an appropriate convergence criterion is satisfied.

The question then turns to specifying the initial values for X_{t-i}^+ , $t-i < 0$ (the convergence criterion will be dealt with below). This is a well-investigated problem in the econometric literature and suggestions have been made that the iteration should begin by setting X_{t-i}^+ $t-i < 0$ to zero and then leave the iteration 6.11 to re-equilibrate and hence generate 'true' values of X_{t-i}^+ , $t-i < 0$ (Dhrymes et al 1970, Dhrymes 1971). However, Maddala and Rao (1971) and Gollnick (1975) have shown that the series generated by the iteration 6.11 in such a manner (by setting initial X_{t-i}^+ $t-i < 0$ to zero) may not be optimally defined. What is more important in practice is that if the true initial values of X_{t-i}^+ , $t-i < 0$ are not zero, then the iteration 6.11 may not have the data to converge to its 'true' structure over a short time-series and when a longer series is unavailable.

The analysis must be case-specific. Since we are dealing with what is essentially an iteration composed of prices in the store markets then there is no a priori reason to expect any combination of prices to be zero. We begin the iteration 6.11 by setting X_{t-i}^+ , $t-i < 0$ to a long-term average rather than zero, the formula for which is easily derived, from equation 6.10.

$$X_t^+ = B(L)^{-1} X_t$$

To establish unique values of gamma and epsilon new variables are formed from equation 6.17 for estimation purposes:

$$X_t = \gamma \tilde{X}_{t-1}^+ + \epsilon \tilde{X}_{t-2}^+ \quad (6.18)$$

where

$$\tilde{X}_{t-1}^+ = X_{t-1}^+ - \epsilon' X_{t-2}^+ \quad (6.19)$$

$$\tilde{X}_{t-2}^+ = X_{t-1}^+ - X_{t-2}^+ \quad (6.20)$$

The value of ϵ' in equation 6.19 is set by initial grid-search and the values of gamma and epsilon in equation 6.18 are estimated by Ordinary Least Squares.

Once equation 6.18 is estimated and values of gamma and epsilon have been found these estimates are then used as a basis to define values for a finer grid-search and the whole process just described is repeated until a minimum sum of squares of equation 6.18 is found.

The second stage of the two-step estimation procedure is rather simpler. Once optimal expectations have been defined then these values are inserted as appropriate expectations variables in the main equations 6.1 and 6.3.

This, however, does not describe the generation of expected risk. Risk is defined to be

$$R_{it} = E\{(X_{it} - E(X_{it}))^2\} \quad i = 1,2 \quad (6.22)$$

This is a difference equation for X_t and the long-run solution to this equation involves removing the lag structure or lag operators (Allen 1956) so that the polynomial, $B(L)$, becomes

$$B(L) = 1 - (\gamma' + \epsilon') + \gamma'\epsilon' \quad (6.12)$$

whereas it was previously defined as

$$B(L) = 1 - (\gamma' + \epsilon')L + \gamma'\epsilon'L^2$$

Expanding equation 6.12

$$B(L) = 1 - (1 - \gamma) - (1 - \epsilon) + (1 - \gamma)(1 - \epsilon)$$

which is equivalent to

$$B(L) = \gamma\epsilon \quad (6.13)$$

Thus a long-term average value of X_{t-i}^+ , $t-i < 0$ may be defined as (see App. 4 for the general case)

$$X_{t-i, t-i < 0}^+ = (4\gamma\epsilon)^{-1} \cdot \sum_{k=1}^{k=4} X_{t-k} \quad (6.14)$$

where the 'long-term' is set by equation 6.13 and the 'average' component by $\frac{1}{4} \sum_{k=1}^{k=4} X_{t-k}$. Thus, the 'average' value is for a specific period prior to the sample estimation period ($t-i < 0$ being arbitrarily set), which is adjusted to a longer-term notion by the product of the adjustment coefficients.

From the iteration 6.11 two average values are required for X_{t-1}^+ and X_{t-2}^+ so the appropriate estimators are

$$\mu_1 = \hat{X}_{t-1}^+ = (4\gamma\epsilon)^{-1} \cdot \sum_{k=1}^{k=4} X_{t-k}$$

$$\mu_2 = \hat{X}_{t-2}^+ = (4\gamma\epsilon)^{-1} \cdot \sum_{k=2}^{k=5} X_{t-k}$$

Hence the iteration can begin by re-specifying the iteration 6.11 as

$$X_t^+ = V_{1t} + \mu_1 V_{2t} + \mu_2 V_{3t} \quad (6.15)$$

where

$$\begin{aligned} V_{1t} &= X_0 & t &= 0 \\ &= X_1 + (\gamma' + \epsilon')X_0 & t &= 1 \\ &= X_t + (\gamma' + \epsilon')V_{1t-1} & t &> 1 \end{aligned}$$

$$\begin{aligned} V_{2t} &= (\gamma' + \epsilon') & t &= 0 \\ &= (\gamma' + \epsilon')^2 - \gamma'\epsilon' & t &= 1 \\ &= (\gamma' + \epsilon')V_{2t-1} - \gamma'\epsilon'V_{2t-2} & t &> 1 \end{aligned}$$

$$\begin{aligned} V_{3t} &= -\gamma'\epsilon' & t &= 0 \\ &= -(\gamma' + \epsilon')\gamma'\epsilon' & t &= 1 \\ &= (\gamma' + \epsilon')V_{3t-1} - \gamma'\epsilon'V_{3t-2} & t &> 1 \end{aligned}$$

Full derivation in App. 4.

Once a series for X_{t-i}^+ is fully defined, which has been based on initial estimated of X_{t-i}^+ , $t-i < 0$ and on the grid-search values for gamma and epsilon, we can then use these generated values to insert into the previously established equation

$$X_t^* = A(L) X_t^+ \quad (6.16)$$

We refer back to defining estimated values of gamma and epsilon on the basis of equilibrium by setting $X_t^* = X_t$ so that equation 6.16 becomes

$$\begin{aligned} X_t &= A(L) X_t^+ \\ &= (\gamma + \epsilon)LX_t^+ - (\epsilon + \gamma\epsilon')L^2X_t^+ \\ &= (\gamma + \epsilon)X_{t-1}^+ - (\epsilon + \gamma\epsilon')X_{t-2}^+ \end{aligned} \quad (6.17)$$

and the AE mechanism is used to define its expectation

$$R_{it}^* = R_{it-1}^* + \alpha (R_{it-1} - R_{it-1}^*) \quad (6.23)$$

where, for the sake of simplicity, we do not define a trend term. The adjustment coefficient in this case is measured as alpha. These generated values are then inserted into the main equations 6.1 and 6.3 as the appropriate risk expectations. Risk expectations are thus generated in an analogous manner to the main expectations just described.

Finally, the generation of expected covariation is described. It has already been mentioned that a problem exists when covariance is defined on the basis of expectations in its component variables which have inherently different lag structures (FT_{1t}^* and DC_{3t}^* were given as examples). If, as we do, define FT_{1t}^* and DC_{3t}^* in the store dairy example as

$$FT_{1t}^* = FT_{1t-2}^* + \gamma_1 (FT_{1t-2} - FT_{1t-2}^*) + \Delta FT_{1t}^*$$

$$DC_{3t}^* = DC_{3t-6}^* + \gamma_3 (DC_{3t-6} - DC_{3t-6}^*) + \Delta DC_{3t}^*$$

then over what lag structure should expected covariation be defined? Actual covariation is easy enough to generate but we have no grounds, on the basis of the lags inherent in FT_{1t}^* and DC_{3t}^* , to decide on the expected covariance lag structure; that is, set 'j' in the equation

$$COV_{13t}^* = COV_{13t-j}^* + \tau (COV_{13t-j} - COV_{13t-j}^*) \quad (6.24)$$

In fact, that covariance adjustment parameter, τ , cannot be freely estimated on the basis of equation 6.24 because there is no solution to the lag problem within the AE framework that has been established. Instead, we constrain τ to lie within the region of estimated adjustment coefficients for the respective risk variables on FT_{1t}^* and DC_{3t}^* . The constraint relation between them is simply established on intuitive basis. The concept of a 'sufficient statistic' is used to simplify the analysis (Newbery and Stiglitz 1981, Sec. 11.4.1). Exactly how this simplification works will be shown below.

A sufficient statistic may be defined as:

"If there is a set of statistics which provides all the information which can be obtained about some random variable, say price, then we say it constitutes a set of sufficient statistics for price; that is, given an observation of the set of sufficient statistics, the estimate of the distribution of price is the same as it would be if we observed those statistics plus any additional statistics."
(Newbery and Stiglitz ibid. pg 154)

Thus, the objective is to define a sufficient statistic for the adjustment parameter of expected covariation.

Now, from the statistical theorem outlined in equation 6.2, the sum of any two related variables have the variance

$$\text{Var}(X+Y) = \text{Var}(X) + \text{Var}(Y) + 2.\text{Cov}(X,Y)$$

and if we substitute FT_{1t}^* for X and DC_{3t}^* for Y we have:

$$\text{Var}(FT_{1t}^* + DC_{3t}^*) = R_{1t}^* + R_{3t}^* + 2\text{COV}(FT_{1t}^*, DC_{3t}^*) \quad (6.25)$$

Recall that the regression equations 6.1 and 6.3 are implicitly weighted 'sums' (weighted by their coefficients) of variables on the RHS which 'explain'

variation in the dependent variable so that equation 6.25 is an accurate form of the variance of the sum of FT_{1t}^* and DC_{3t}^* . We also know from the extension of the theorem (equation 6.2) that when coefficients are added to the sum of our variables to account for underlying different units of measurement that its variance becomes

$$\begin{aligned} \text{Var}(\beta_1 FT_{1t}^* + \beta_3 DC_{3t}^*) &= \beta_1^2 \text{Var}(FT_{1t}^*) + \beta_3^2 \text{Var}(DC_{3t}^*) \\ &\quad + 2\beta_1\beta_3 \text{COV}_{13t}^* \end{aligned} \quad (6.26)$$

which reveals the nature of the relationships between the variances and covariance in terms of the coefficients β_1 and β_3 . That is, the coefficient on the covariance term $2\beta_1\beta_3$ is simply a product of the coefficients on the variance terms β_1^2, β_3^2

It is therefore assumed that the adjustment coefficient parameters for R_{1t}^* and R_{3t}^* (α_1 and α_3) have the same relation to the adjustment parameters for expected covariance(τ) as the relation between the β_i in equation 6.26. That is, the expected covariance adjustment parameter (τ) may be set equal to $\sqrt{\alpha_1 \alpha_3}$, which is the analogy of the β_i relations in equation 6.26. Thus we regard $\sqrt{\alpha_1 \alpha_3}$ as a sufficient statistic to τ in equation 6.24. No formal proof of this result can be given but it is expected that this intuitive explanation cannot be too poor an approximation.

Now, expected covariance can be written as (c.f. equation 2.10, Sec. 2,4,1):

$$\text{COV}_{13t}^* = \sqrt{\alpha_1 \alpha_3} \cdot \sum_{i=0}^{\infty} (1 - \sqrt{\alpha_1 \alpha_3})^i \cdot \text{COV}_{13t-i-1} \quad (6.27)$$

where the lag on actual covariance ($t-i-1$) can now be realistically set to $i=1$ (one quarter) because the adjustment parameters α_1 and α_3 already account for any inherent differences in the lag structures involved in FT_{1t}^* and DC_{3t}^* . That is α_1 and α_3 are adjustment parameters for quarterly predictions which have been estimated on the basis of $P/E=2$ and $P/E=6$,

respectively; and hence they are based on the different production lags involved in FT_{1t}^* and DC_{3t}^* .

Thus, the form in equation 6.27 is used to define expected covariance and constrain its adjustment coefficient to be in accordance with the adjustment coefficients for the related risk estimates; that is $\tau = \sqrt{\alpha_1 \alpha_3}$.

6.5.2 The Significance of Aggregated Risk

Previous econometric studies of risk analysis typically involve only one risk variable, or the same risk variable lagged a number of times (Behrman 1968, Traill 1978). We have seen that we may include as many as six such variables in the Dairy equation 6.3. It may therefore be useful to examine the nature of some form of aggregated risk variable to compare with other works.

This is quite easily achieved from the results to be shown and does not require separate estimation. Under the column headed 'T' in Tables 6.3 - 6.7 are to be found t-statistics referring to the implied aggregated (single) risk variable relating to each equation that is estimated. The sign of the statistic indicates the direction of influence of the variable. The actual coefficient is not given because its interpretation is obscured by the combination of different units of measurement in their sample data. The t-statistic does have a clear economic meaning, however, in the sense that it measures the strength of influence of total or aggregated risk in the store purchaser's mind.

The measure of aggregated risk is derived from a restriction inherent in parameter relations of the two main equations 6.1 and 6.3. The example illustrated is for beef, pigs and sheep but is readily extended.

We refer again to the statistical theorem outlined in equation 6.2. This has an obvious relation to the main equation 6.1 where, for illustrative purposes, we present expectations and risk variables only; that is

$$SC_t = \beta_0 + \beta_1 FT_{1t}^* + \beta_2 FD_{2t}^* + \beta_3 R_{1t}^* + \beta_4 R_{2t}^* + \beta_5 COV_{12t}^* \quad (6.28)$$

and R_{it}^* are defined as variance measures; viz

$$R_{1t}^* = \text{Var}(FT_{1t}^*) = E (FT_{1t} - FT_{1t}^*)^2 \quad (6.29)$$

$$R_{2t}^* = \text{Var}(FD_{2t}^*) = E (FD_{2t} - FD_{2t}^*)^2 \quad (6.30)$$

$$COV_{12t}^* = COV_{12t}(FT_{1t}^*, FD_{2t}^*) = E\{(FT_{1t} - FT_{1t}^*)(FD_{2t} - FD_{2t}^*)\} \quad (6.31)$$

Therefore, the combination of coefficients and variables

$$z = \beta_1 FT_{1t}^* + \beta_2 FD_{2t}^* \quad (6.32)$$

have the variance

$$\text{Var}(z) = \beta_1^2 \text{Var}(FT_{1t}^*) + \beta_2^2 \text{Var}(FD_{2t}^*) + 2\beta_1 \beta_2 COV_{12t}^* \quad (6.33)$$

But from the equations 6.29-6.31 we have redefined variances (including their coefficients to account for differing units of measurement in the sample data) so that equation 6.33 can be written as

$$\text{Var}(z) = \beta_1 \beta_3 \text{Var}(FT_{1t}^*) + \beta_2 \beta_4 \text{Var}(FD_{2t}^*) + 2\beta_1 \beta_2 \beta_5 COV_{12t}^* \quad (6.34)$$

Hence, if we combine risk to form an aggregated measure on the basis of equation 6.32 and the result in equation 6.33, and note our own definitions of risk in equations 6.29-6.31, the implied coefficient relation is derived in equation 6.34

$$y = \beta_1^2 \beta_3 + \beta_2^2 \beta_4 + 2\beta_1 \beta_2 \beta_5 \quad (6.35)$$

where 'y' is the coefficient of the aggregated risk variable. The variance of the aggregated measure of risk is asymptotically equal to:-

$$\text{Var}(y) = c' \Sigma c$$

where

$$c' = (\beta_1^2 , \beta_2^2 , 2\beta_1 \beta_2)$$

and Σ is the appropriate submatrix from the already estimated Var/Cov matrix which is routinely calculated as part of the results of most statistical and econometric software packages.

This analysis is easily extended to the simultaneous framework that is used in Chapter 7 where we shall refer back to this result.

6.5.3 Lag Structures for Adaptive Expectations

It has already been stated that the two-step estimation procedure outlined in Sec. 6.5.1 precludes the requirement for lag structures in the main equations 6.1 and 6.3. The lag structure defined by the P/E ratio must enter the analysis at some point in order for the expectations variables to represent dynamic adjustment in the store markets. We shall describe in this section exactly what lag structures have been used. In all examples mentioned quarterly predictions based on quarterly data are required.

The lags are defined within the Adaptive Expectations hypothesis where predictions are made over different production-runs ('P' in the P/E ratio). A one-quarter lag for the AE hypothesis (shortest in relation to the data) is chosen to define all expected feed variables, because it is necessary to feed the animals continuously. This lag was also adopted for the fattening processes in the pig and sheep sectors as it takes about 3 months to fatten an animal from a store; hence $P/E=1$ for these expected fatstock prices and for all expected feed prices. These lags are, of necessity, approximations but reflect what is happening on the average.

A $P/E=1$ is also used for both steer and heifer expected fatstock price which was thought reasonable as the dependent variables were two-year old stores.

The dairy market is more complicated. Let us briefly examine a simplified life-cycle for one animal entering a milking herd as a purchased replacement. Purchased replacements for dairy herds are either stores or down-calvers. Down-calvers are, in fact, used as the dependent variable. The animal enters the herd and produces a calf at which point it begins its first lactation. If it turns out that the animal is a poor milk producer, or as sometimes is the case, it is injured or becomes ill and is unable to produce a sufficient amount of milk, then it will be sold as beef. We assume that the purchaser of store stock will realise the production characteristics of any particular cow fairly quickly, and at least within 6 months of it entering the herd, so that we set $P/E=2$ on expected fatstock price in the dairy equation as a representation of the animal's sale onto the beef market.

For average dairy farms fairly high milk yields are required from all cows. This then specifies the typical length of time any one store purchase will remain in the herd because milk productivity declines after the second or third lactations. We set $P/E=6$ quarters as an approximation to half of the length of the animal's productive life as a dairy cow. This defines the lag

on expected dairy cow price which measures the value of a transfer of stock into other herds so that the implication is that the cow still has a productive life, but is not sufficiently productive to keep the cow in certain (productive) herds. Alternatively, many sales of dairy cows into other herds occur because of 'trouble' with the cow. This can be taken at its most vague meaning because 'trouble' may be a multitude of things with which the farmer is dissatisfied; for example, poor milk yield, disease proneness, calving difficulties, etc. Dairy cow transfers at $P/E=6$ are in general accordance with the evidence available on the lactation structure of some recorded herds where a large proportion of stock never reach beyond two lactations (See App. 4 for details).

When the lag structures have been defined for all the main expectations (fatstock and feed prices) then their associated expected risks have the same dynamic response, and so do the expected covariances between the main expectations, the estimation of which has been outlined in Sec. 6.5.1.

6.6 Results and Analysis

As a precursor to the investigation of expectations and risk in the store demand equations we establish what we shall call the 'basic relations' in the demand for store animals. That is, how an econometrician would estimate store demand without specifying a role for expectations and hence without allowing a role for risk. The main results are then presented and elasticity estimates are produced from these.

6.6.1 Basic Relationships

The basic relationships are assumed to represent the underlying price movements in the store markets as explained by the demand for stores. This refers to simple associations between store prices, on the one hand, and fatstock and feed (plus dairy cow price for the dairy equation) prices, on the other. Alternatively, the equations may be looked upon as the long-term

equivalent of the main equations where all expectations are equal to their actual values and risk becomes redundant. Their main purpose, however, is to indicate the fundamental relationships between the data sets with which we work.

TABLE 6.1 BASIC DEMAND RELATIONSHIPS IN THE STORE MARKETS

MODEL	Constant	FT	FD	DC	$\hat{\rho}$	DW	F	$\bar{R}^2$
Steers	22.542 (11.805)	3.573 (0.318)	0.084 (0.131)			1.722	72.695	0.769
Heifers	37.245 (15.310)	2.817 (0.354)	0.058 (0.184)		0.603 (0.128)	2.108	56.337	0.725
Pigs	9.151 (1.881)	0.156 (0.042)	-0.066 (0.021)		0.812 (0.085)	1.503	25.313	0.537
Sheep	5.147 (1.766)	0.067 (0.019)	0.009 (0.027)		0.659 (0.115)	2.194	20.268	0.479
Dairy	-69.599 (27.144)	0.569 (0.322)	0.095 (0.255)	0.529 (0.255)	0.459 (0.141)	2.285	27.905	0.658

With reference to this and all other tables figures in parentheses are asymptotic standard errors. $\hat{\rho}$ is the Maximum Likelihood estimate of the first-order serial correlation coefficient and appears only when the appropriate transformation has been undertaken. DW is the Durbin-Watson statistic to test for serial correlation. F is Fisher's statistic with the null hypothesis of zero significance on all coefficients of the RHS variables. $\bar{R}^2$ is the multiple correlation coefficient. All the variables used have been defined in Sec. 6.2. Sample size = 44.

The results reveal that most of the significant variation in store prices from the demand side arises from the influence of fatstock prices. Presumably, if the farmer can be assured of a 'good' sale value for his product then he will take care of the means to get it into a saleable condition. That is, the farmers in the various markets seem primarily concerned with fatstock sale value whilst the effects of feed costs appear to be background considerations.

The sign on all but one of the feedgrain price coefficients (that for pigs) is incorrect. Feed price should, a priori, have a negative influence on store price because if feed prices rise then this will make feeding store animals more costly; this will reduce profit margins, hence demand will fall and store price with it. However, the insignificance of all positive feed variables indicates that their influence is not particularly important in the framework in which they have been estimated.

The case of store pigs, on the other hand, is an exception with a significantly negative sign on its feed price coefficient. This is matched by a significantly positive sign on fat pig prices. Clearly, both aspects of store demand are important and this provides tentative support for the specification of the equation which will subsequently be used.

The store dairy equation has an incorrect feed sign, but both fat and dairy cow prices are well represented in terms of statistical significance.

The test statistics ($\hat{\rho}$, DW, F, and R^{-2}) suggest no particular statistical problems but simultaneous bias may be present, however, as a consequence of unrepresented influences from store supply. As mentioned, no particular importance should be attached to these results. They are presented as a starting-point from which a discussion of the role of expectations and risk in the store markets may begin.

6.6.2 Adaptive Expectations Adjustment Parameters

The adjustment parameters for each expected variable that has been generated by the process described in Sec. 6.5.1 are shown in Table 6.2.

Two parameters are estimated for each main expectation (e.g. FT_{1t}^* , FD_{2t}^* , DC_{3t}^*): one for the main adjustment, gamma; and one for the trend adjustment, epsilon. Only one adjustment parameter, alpha, is estimated for changes in expected

risk for reasons already outlined. Alpha can be regarded as a risk-equivalent to gamma; that is, it measures main adjustment in risk, but not trend adjustment. Recall that expected covariation is constrained to satisfy the estimated results for risk and is therefore not presented as a result in Table 6.2.

Note also that the same data is used for feed prices in the store beef (steers and heifers) and sheep markets hence the adjustment parameter estimates are the same. More details on the data used will be found in App. 6.

TABLE 6.2 ADJUSTMENT COEFFICIENTS FOR THE
ADAPTIVE EXPECTATIONS MECHANISM

		Adjustment coefficients on:		
VARIABLES FOR WHICH EXPECTATIONS HAVE BEEN MADE:		Level (gamma)	Trend (epsilon)	Risk (alpha)
STEERS				
Fat		0.543 (0.102)	0.003 (0.001)	0.5E-05 (0.2E-05)
Feed		0.939 (0.078)	-0.018 (0.052)	0.002 (0.003)
HEIFERS				
Fat		0.648 (0.087)	-0.004 (0.001)	0.3E-05 (0.1E-05)
Feed		As beef Steers		
DAIRY				
Fat		0.981 (0.091)	-0.001 (0.059)	1.061 (0.059)
Feed		1.095 (0.058)	0.085 (0.045)	0.6E-03 (0.2E-03)
Dairy		0.006 (0.002)	-0.004 (0.001)	0.6E-03 (0.2E-03)
PIGS				
Fat		0.638 (0.099)	0.003 (0.003)	0.4E-09 (0.1E-09)
Feed		1.057 (0.066)	0.038 (0.036)	0.003 (0.004)

SHEEP

Fat	0.939 (0.077)	00.018 (0.052)	0.083 (0.057)
Feed	As beef Steers		

The main effects concerning movements in the level of expected prices (gamma) confirm a priori predictions, and they represent most of the changes in expectations that take place.

All estimates of gamma in relation to fatstock prices are significant. The steers and heifers figures are much the same which accords with economic reasoning: if they were largely different then this would suggest that beef steers and heifers are operating in distinctly different markets. Steers are beef animals, whilst heifers may be produced as beef or used in the breeding herd of the beef sector. Thus, they both operate in the same market but may be used in a slightly different manner. The expectations adjustments coefficients, gamma, are therefore similar to the extent that steers and heifers may be sold as beef, but different to the extent that heifers may be used for breeding.

Expected dairy fatstock price is fully adjusted over the lag structure ($P/E=2$) we have defined for it. The AE hypothesis in this context acknowledges the fact that most dairy animals will eventually be sold as beef. The statistical significance of the main adjustment coefficient on fatstock price (gamma) suggests that there is a close link between expectations movements and what happens in reality.

The extent to which the beef sale outlet is important in store dairy purchasing will be determined by the parameter estimates in the main equation 6.3. We evaluate the scale of adjustment at this stage and the result on gamma in expectations of dairy fatstock price suggests that expectations adjustment,

from quarter to quarter, is complete.

Similar reasoning to that just described also holds for the main adjustment (γ) on expected fatstock price in the store sheep market where expectations adjustment has been found to be statistically significant. Again, this provides support for the use of the AE adjustment mechanism.

The expected fatstock price for pigs is only partially adjusted over the 3 months ($P/E=1$), as measured by γ , and may be indicative of the extent of variability in the market (the 'hog cycle'). Farmers may consistently make mistakes in forming expectations of the level of fatstock prices. Consequently, they may only partially take into account any new errors in expectations that may be made (the AE hypothesis is an 'error learning' mechanism), which results in less-than complete adjustment. The implication of incomplete adjustment (assuming the lag structure, P/E ratio, to be correct) is that farmers only completely adjust to new information over a longer period of time than one quarter (as we have defined P/E).

Recall that the purpose of defining a P/E ratio in the expectations mechanism is not to generate expectations on the basis of complete adjustment (hence, pre-imposing $\gamma = 1$), but to examine expectations adjustment on the basis of the production periods involved in store demand (in the pig fattening case, one quarter). Complete expectations adjustment and the production periods are not necessarily equal.

Expected feedgrain price adjustment in terms of γ for beef steers and beef heifers is the same because we use the same data for each. There is complete adjustment which compares with the corresponding figures established for the dairy and pig sectors.

All expected feed price adjustment coefficients are in the region of unity. One reason for this is that the main determinant of profitability which is primarily under the control of the farmer is feed costs (he cannot, if he is a price-taker, influence revenue: that is, fatstock or milk prices). The use of artificial feed can, in principle, be altered immediately; although, in practice, it may be a more difficult exercise if the farmer's stock have become used to artificial feeding (of course, the alternatives are less in the pig fattening process). The farmer will have a firm idea, from experience, about the contribution that varying levels of feed input have on output. It is this experience and knowledge of the contributions to revenue (in terms of output) and costs that artificial feed has on profitability, that enables the farmer to be fairly confident about adjusting expectations. Expectations are adjusted, on the basis of the results shown, fairly completely over any particular 3 months (one quarter). This behaviour is likely to be a consequence, not of the predictability of feed prices, but of the known effects of feed to the cost structure of production. Feed costs are an important element of the financial flows of all farm-types examined, it is therefore unsurprising that firm expectations behaviour (in terms of Adaptive Expectations adjustment through γ) is fairly well-defined for all feed variables.

Feedgrain price is common to all of the markets studied in its effect as a cost of producing milking and fattened stock. The price represents the additional feeding cost associated with the extra store that is purchased. Its effect on the store purchasing decision, however, corresponds to the coefficient estimate of expected feed price in the main equation which we shall discuss below.

The figure for gamma in the expected dairy cow price (0.006) is very low, but remains significant. The result suggests that the decision on when to sell a purchased store into another dairy herd cannot be generalised to all purchased stores in the dairy sector. This is because the date of sale is a very variable feature. Even though we set $P/E=6$ on the lag in generating expected dairy cow price, some stock will continue to remain in the same herd for further lactations. In fact, a dairy cow sale into another dairy herd may occur at any time between 1-5 years.

We have only approximated this situation by choosing $P/E=6$; choosing a longer lag is not feasible with the amount of data available. Certainly, expectations can be generated on the basis of longer lags, but the number of 'completed' production periods would be few. That is, if we had set $P/E=20$ (5 years) then we explicitly state that purchased store dairy stock remain in the same herd for five years and that this is the relevant 'production period' (P in the P/E ratio) for this particular stock. The production period in relation to the sample size then becomes quite large: only two production periods are actually completed per sample estimation period (1970-1980). It is therefore unlikely that we would obtain meaningful results on the basis of data that inadequately accommodates the production cycles involved in dairying. We are then, by default, forced to approximate the production period to a shorter frequency, $P/E=6$, which may or may not capture expectations behaviour. Of course, shorter term estimates of dairy cow prices (i.e. $P/E < 6$) can be made but these are only relevant to the simplest resale decisions and may not adequately reflect the dynamic structure of milk production in general.

The conclusion is that it is quite likely that a low estimate of gamma will be found, although a figure of 0.006 suggests that other influences are operating. The result indicates that farmers may have an idea of the likely price to be obtained for the sale of purchased stock into another dairy herd (DC^*_{3t}) at the time the store purchase is made. A figure of 0.006 indicates

little change in expectations over the years. Changes in expectation may therefore be a background consideration in terms of the scale of its influence on store purchasing, but exactly how it affects decision-making in the store market in terms of response will be decided by the coefficient estimates in equation 5.3.

All main effects of expectations adjustment (γ) have significant parameter estimates and in that sense we have established a major component of expectations behaviour as we have defined the AE hypothesis (equation 6.5). The results for the trend adjustment parameter (ϵ) are potentially misleading, however, and require some explanation.

The estimates of all trend effects are generally lower (as expected) than the main adjustment coefficients and are, in some cases, very small. The most notable features of some results are the negative signs on the estimated coefficients (ϵ). This ostensibly appears out of bounds (a priori, $0 < \epsilon < 1$), but their overall significance belies this explanation. What we may be facing is a trend effect on the generation of expectations which is compounded with an overlying cyclical movement. That is, the estimate of ϵ is made up of two components: trend and cycle. Theoretically, we would wish the estimate of ϵ to only represent trend, but time-series can always be explained in terms of such components (seasonality, trend, cycles, etc.) and it is our method which has failed to distinguish trend from cycle.

In relation to the discussion of the P/E ratio describing the relative frequencies of the production-run against the length that expectations are made (prediction length), the cyclical movement of the prices which enter expectations has a longer frequency than trend which is confounding the estimate of ϵ . If it is the purpose of the analytical method which specifies expectations behaviour to identify the components of such behaviour

(changes in the level of expectations, changes in its trend) then we have failed to identify the cyclical component. The negative sign suggests that, on average, the markets with negative epsilons are associated with a counter-swing in the cyclical movement of the underlying economic quantity which is potentially stronger than any short-term trend effect over the sample period of estimation.

There is nothing that can reasonably be done about this underlying cycle since its identification in terms of an adjustment parameter under the AE hypothesis would be extremely costly in terms of data requirements. Cycles in economic quantities generally run over many years and it would therefore be presumptuous to attempt to establish the time-series properties of a cycle with quarterly data covering eleven years (Dhrymes 1970).

The difference in signs of the trend effects in the two beef sectors also requires explanation. It has already been mentioned that heifers may either be sold as beef or used in the breeding herd and that a negative sign on the trend term suggests a dominant cyclical component to expectations behaviour over trend. It is also recognised that economic cycles are associated with longer-term economic conditions. However, investment in herd size which is effected through the retention of heifers in the breeding herd is associated with longer-term economic conditions, since herd investment represents the farmer's view of the viability of his operation over some years.

The conclusion is that the farmer may therefore consider cyclical movements in heifer prices as more important elements in expectations formation than trend movements. This is because the time horizons associated with cycles may be more accurate at reflecting the farmer's longer-term view of the economic viability of his farm as represented by expanding the herd. In turn, this will mean that cyclical behaviour on the formation of expectations concerning expected heifer fatstock prices is more important than variable trend behaviour: hence a negative epsilon (-0.018) for opposed swings in cycles and trend.

This does not mean to say that trend is entirely unimportant. Even a zero epsilon indicates that trend may be accounted for in a constant manner.

Expectations of beef steer fatstock prices have a positive relation with movements in trend. If the cyclical explanation of negative epsilon is accepted then it must also be accepted that a positive trend term may be reinforced by complementary cyclical movements. This may be the case in the beef steers example for expected fatstock prices although the more obvious reasoning would be that the trend adjustment parameter is correctly specifying trend movements in expectations. This is because it is harder to justify longer-term cyclical behaviour in fatstock steer prices that dominate the trend effect on expectations formation. The cyclical behaviour will probably exist, but there is little reason to suspect that it is significantly influencing trend.

Trend adjustment on beef feed prices (and hence on sheep feed prices) is also negative. This may reflect a relatively longer-term (cyclical) view of prices in the feedgrain markets which are contrary to their associated trend movements. The result, however, is insignificantly different from zero and hence we cannot infer too much in terms of economic explanation.

The results for trend adjustment in the dairy sector suggest a statistically significant sign on expected dairy cow price (-0.004) whilst expected fatstock and dairy feed price trend terms are both insignificantly different from zero. Because of the low value of epsilon for some prices we must infer that the addition (or subtraction) in expected prices appropriate to trend must be fairly steady.

Expected dairy cow price trend positively contributes to the determination of the total expectation of dairy cow price and, to an extent, contradicts the negative results for the trend in expected feed prices in the beef market.

It could be presumed, on theoretical grounds, that the two markets would at least move in sympathy with one another. The fact that the trend result on expected dairy cow price is both statistically significant and positive would indicate that this result more accurately reflects the true situation with regard to expectation formation under the AE hypothesis. The insignificantly negative (and theoretically opposed result to the dairy market) epsilon on expected beef feed is perhaps an incorrect estimate of the true situation.

Insignificantly positive results were obtained on both trend terms in the pig market and an insignificant negative result obtained for expected fatstock sheep price. These require no comment in themselves since the conclusions previously drawn are relevant. We wish, however, to draw attention to the relationship between all trend estimates (epsilon) and their corresponding level estimates (gamma).

A pattern seems to emerge in a comparison of the two components of expectations behaviour estimated in Table 6.2 in that the least significant trend results appear to be associated with full adjustment in the level of expectations (e.g. beef feed for steers). On the other hand, those trend estimates which approach statistical significance are associated with less-than-full adjustment in the changes of the level of expectations as measured by gamma (e.g. fatstock price on steers).

Perhaps any deficiency in the adjustment in one parameter is being compensated for in the other parameter; and when one is fully adjusted (close to unity) then this seems to preclude a contribution to adjusting expectations from the other parameter. However, the combined results of level and trend adjustment should not be assumed to sum to unity because they inherently measure response to adjusting expectations in fundamentally different economic quantities. That is, gamma measures adjustment in the level of expectation; epsilon measures adjustment in its associated trend (first difference). There are no theoretical

reasons why adjustment of the level and trend (and possibly cycle) of an economic quantity should, in some way, sum to unity. On a priori grounds, we have already mentioned that the likely bounds of gamma and epsilon lie between zero and unity. Hence, they could potentially sum to 2.

The fact that gamma and epsilon measure adjustment in different components of a time series does not rule out some relation between them. They are, after all, parameters derived from the same time series. If the level of fatstock prices continues to rise, for example, then this will eventually become a trend which will eventually become a part of the cycle. The problem faced in the estimation of gamma and epsilon is that it has been difficult to establish where the trend effect of expectations adjustment ends and its cyclical effect begins. In this sense, level, trend and cycle are parts of the same economic time series which are only vaguely distinguishable on the grounds that they occupy different temporal spheres: cycles are longer frequencies than trend adjustment; trends are a longer frequency of adjustment than in the level of expectations.

The adjustment coefficients for the generation of expected risk (alpha) are generally low compared with the other results. All estimates are correctly signed on a priori grounds.

Steers and heifer fatstock risk are more or less of the same magnitude and follows the reasoning given for the similarity of magnitude of their other adjustment coefficients: that is, steers and heifers are components of the same markets and should therefore have similar economic statistics. The figures for risk ($0.5E-05$ for steers and $03E-05$ for heifers) are low and represent a fairly unchanging method of evaluating the scale of risk. In other words, it would take a large amount of variability in each of the fatstock markets for steer and beef heifers to induce any change in the way risk expectations should be measured.

The scale of these results compares with the figure for risk in the evaluation of expected dairy cow price. The statistical significance also compares and indicates that the AE hypothesis and our own econometric method are capturing the appropriate movements in the data through time which enter in the calculation of risk expectation.

The magnitude of this particular result also compares with the corresponding results for level and trend expectation adjustment in expected dairy cow price. That is, although the figures are statistically significant they represent only a small degree of adjustment of expectations to changes in the real (observable) data. This fits in with the conclusions previously drawn in that it is difficult to generalise on the lag structure to determine when the sale of the purchased store occurs into another dairy herd; hence the estimate of alpha is only weakly defined because the expectations which compose it are also only weakly defined.

This is not the case, however, with the estimated risk adjustment coefficient for fatstock price in the dairy sector (1.061). There is slight over-adjustment but the point to emphasise is that the coefficient is of greater magnitude than the level adjustment coefficient for the same expectation (0.981). On a priori grounds this is a very unusual result. It suggests that expectations, defined by the AE hypothesis, strongly reflect what is actually happening in the market. That is, variability in the fat cow market can be accurately assessed in terms of the AE hypothesis when risk is measured by variance; although exactly what influence subjective fatstock dairy price has on the store purchasing decision cannot be evaluated on the basis of this estimate alone.

Generally smaller figures for risk adjustment are to be found for beef feed, dairy feed, pig feed and fatstock sheep prices (0.002, 0.006, 0.003 and 0.083, respectively). They are in accordance with the previously estimated results for their associated level and trend adjustment coefficients in that risk adjustment is smaller than level adjustment.

Finally, the risk adjustment coefficient on expected fatstock pig price risk is very small ($0.4E-09$), but surprisingly significant. This means that expected risk is evaluated at a constant level and remains unchanged over the farmer's lifetime. Recall that the data has been deflated and deseasonalised so that we are examining real movements in expectations so that a constant level of risk is a possibility given that there are no other extraneous influences operating.

The implication of a constant scale of risk is that changes in pig fatstock from changes in risk being too variable to predict and hence a simple average view is taken, or that expected risk does not change because risk, in reality, is a constant.

This analysis and the discussion of the other results is only basically a statistical analysis of the generation of numbers (expectations). We can only infer greater economic content from the coefficient estimates of subjective risk in the main equations 6.1 and 6.3 to which we now turn.

6.6.3 Main Results: Estimation of Equations 6.1 and 6.3

Once the expected variables have been generated, based on the results of the previous section, these values can be inserted into the main equations 6.1 and 6.3 to derive consistent estimates of their effect on the determination of store demand.

Tables 6.3 - 6.7 provide the parameter estimates for the models. We have also estimated store demand equations based on the expectations we have defined but excluding the effect of risk. These are known in the tables as 'conventional estimates' of store demand.

Conventional estimation is undertaken for comparative purposes. One rationale for estimating coefficients of risk is that, should risk be an important feature

of store demand, the inclusion of risk improves the estimates of the other parameters in the equation. Conversely, if risk is important and is excluded from estimation then we may obtain biased estimates of coefficients as a result. The conventional and 'risk' equations are therefore presented together to indicate what effect the inclusion of risk has on store demand.

All equations have been estimated by Ordinary Least Squares (OLS) and standard autocorrelation transformations have been undertaken when the existence of autocorrelation has been found to be significant. This will be clear from the content of the tables where an estimate of ρ (rho: first order serial correlation coefficient) is included when the transformation has taken place.

We are well aware of the inconsistent estimates of both coefficients and standard errors when autocorrelation and a lagged dependent variable appear together in an equation (Johnston 1972). When this occurs Maximum Likelihood (ML) methods are used to provide consistent estimates of ρ and validate, in principle, the autocorrelation transformation.

In some cases where Durbin's h-statistic (Durbin 1970), to test for the existence of serial correlation when a lagged dependent variable appears in the equation, fails, the combined evidence of the Durbin-Watson statistic and estimated ρ are used to form a view on the likely existence of autocorrelation. This occurs in only one case in the store beef heifers equation (Table 6.4.)

Autocorrelation is considered to be the severest econometric problem for our own analysis because the validity of the results rests on the significance of the parameter estimates. It is therefore crucial to, at least, provide asymptotically correct estimates of the standard errors of the coefficients which is not possible when autocorrelation occurs. This is, in fact, an important feature of the entire analysis and will be extended in a simultaneous framework in Chapter 7.

TABLE 6.3 REGRESSION ESTIMATES FOR STORE BEEF STEER DEMAND

	Risk Equation	Conventional Equation
Constant	56.817 (28.625)	12.636 (24.458)
FT_{1t}^*	2.200 (0.942)	3.833 (0.842)
FD_{2t}^*	-0.391 (0.271)	-0.469 (0.265)
R_{1t}^*	9.984 (7.499)	
R_{2t}^*	-7.764 (5.138)	
Cov_{12t}^*	0.084 (0.128)	
LN_{t-1}	0.071 (0.029)	0.049 (0.025)
Hay_t	-0.517 (0.363)	-0.048 (0.355)
T (Aggregated Risk)	1.357	
TEST STATISTICS:		
DW	2.025	1.922
F	9.437	11.819
R^2	0.579	0.502

Table 6.3 presents the results for the store beef steers market. Largely significant results are produced on the expectations variables although only 80% significance is achieved on expected feed price and the two risk variables. Expected covariance risk is insignificant.

The expectations variables have interesting signs with the effects of risk, in particular, being in accordance with the analysis of official intervention in the beef fatstock markets in Sec. 3.3. That is, a floor existed in the study period (1970-1980) below which fatstock beef prices were not allowed to fall in any one year. This was not matched, however, by any ceiling on prices.

Therefore, any variation (risk) in fatstock prices would be welcomed by farmers purchasing store stock because they know that the market will be supported from below by official policy. The effect of subjective risk associated with a shortfall of sale income in finished stores in the fatstock markets would be ruled-out because of official support, whilst the possibility existed for profit-taking should prices rise. This preference for fatstock price increases over and above the intervention or support levels would manifest itself in a positive coefficient for fatstock price risk because the market prices below support levels are ruled-out by official policy; that is, market prices below support levels can have no implications for risk perception in the fatstock markets. In other words, what farmers prefer is the higher mean value of fatstock price (and hence sale income) associated with increased variability (risk). A higher mean value can only be defined in relation to an average fatstock price level. The average level is set by market support (for example, the intervention price) and hence variability in prices above this induces the expectation of greater profitability. Variability below this has no effect since support measures will then be effective.

This is not the case, however, with risk associated with expected feed prices. A negative coefficient has been estimated which indicates that farmers dislike unexpected variation in feedgrain prices. We know from the sign of expected feed price variable that it depresses store price. Thus, from a store demand point of view, increases in expected feed prices inhibit the purchasing of stores. If expected variability (risk) in these prices is likely to be large then this will inhibit purchases still further.

The alternation in the signs of the risk coefficients in the store beef steers demand equation justifies the equation specification. We have identified the components of risk in the store purchasing decision mechanism as far as the data will allow. Had we estimated just one risk variable to represent per unit profitability on the marginal store animal then some potentially confusing

results would have arisen. The evidence for this statement appears in the t-statistic for the implied aggregated risk variable in the equation under the title 'T' in Table 6.3. The positive sign of this indicates a positive aggregated risk coefficient. From this figure alone we would have been forced to conclude that farmers are prone to purchase more stores should variation in net profitability increase.

The separation of net profitability into revenue (fatstock price) and costs (feedgrain price) of the marginal store animal identifies which components of risk are arising as the main influence in the aggregated risk variable. Because the aggregated variable has a positive t-statistic then it will also have a positive coefficient. This implies that subjective fatstock risk dominates the influence arising from subjective feed price risk. If the converse were true then the aggregated variable would have an implied negative coefficient.

This result also accords with the conclusions drawn from the basic relationship for store beef steers estimated in Table 6.1. We found that most of the explanation of store demand in the basic result emanated from actual fatstock price. It is unsurprising, therefore, that expected fatstock price risk should dominate expected feed price risk as implied in the aggregated risk variable result in Table 6.3. A positive aggregated result suggests that potential sale revenue is uppermost in the farmer's mind when purchasing stores.

Expected covariance risk is insignificant. Its positive sign indicates, however, that as long as an expected deviation of actual feed costs from its expected value is matched by a deviation in fatstock prices of a similar sign then this will contribute extra demand for stores. In this respect, a positive covariance risk sign supports the dominance of fatstock price risk mentioned above.

The potential entrants onto the store market, as measured by lagged livestock numbers, is correctly signed (positive) as far as store demand is concerned. The increase in numbers will lower their supply price onto the market thereby lowering their buying-in price for the store purchaser. As a motivation for buying more store stock, then a positive influence from lagged livestock numbers acts as an incentive. If this interpretation is correct then lagged livestock numbers enters the equation as a demand variable and not solely as a supply variable as we originally intended.

If lagged livestock numbers is not a demand variable then it is incorrectly signed. Its interpretation must then be phrased in terms of a supply-side variable alone. That is, it enters the demand equation to account for potential problems of simultaneity with a negative influence on store price (because any increase in the quantity of stores entering the market will reduce their price).

Hay price is correctly signed and significant in the store beef steers demand equation. We have mentioned that this price is taken to represent a shadow price of grazing. The results suggest that this is quite a separate influence on the feeding cost structure of store animals which is over and above the contribution made by artificial feed costs (as measured by expected feed price). Both variables have their role to play in influencing store demand.

The conventional counterpart to the store beef steers 'risk' equation indicates a greater significance for the role of expected fatstock and feed prices. The results reiterate what has already been said concerning the motivation for estimating the conventional equation: that is, the existence or absence of risk affects other coefficient estimates should its underlying influence be significant.

Thus, we see in Table 6.3 that the existence of risk variable in the store demand equation significantly alters the coefficient estimates on other variables in the equation, notably expected fatstock and feed prices.

Attention should also be drawn to the statistical insignificance of Hay price in the conventional equation compared with its statistical significance in the risk equation. The inclusion of the risk variables appears to have sharpened the distinction between expected feed price and hay prices. This assists in their interpretation as contributing to store demand. The fact that both variables are statistically significant in the risk equation suggests that expected feed price measures the additional artificial feeding cost that the extra purchased store will impose, whilst hay price is an indication of grazing availability. From this point of view, the two variables measure the influence of two quite separate components of store demand.

TABLE 6.4 REGRESSION ESTIMATES FOR STORE BEEF HEIFER DEMAND

	Risk Equation	Conventional Equation
Constant	66.349 (16.987)	36.374 (13.645)
SC_{t-1}	0.952 (0.146)	0.905 (0.158)
FT_{1t}^*	-1.078 (0.886)	0.153 (0.849)
FD_{2t}^*	-0.301 (0.151)	-0.407 (0.157)
R_{1t}^*	2.410 (1.535)	
R_{2t}^*	-1.834 (0.862)	
Cov_{12t}^*	0.129 (0.111)	
Hay_t	-0.197 (0.228)	0.075 (0.219)
T. (Aggregated Risk)	1.061	

TEST STATISTICS:

$\hat{\rho}$	-0.474 (0.144)	-0.381 (0.146)
h	-1.948	Fails
DW		2.086
F	42.827	45.872
$-2R$	0.875	0.819

h is Durbin's (1970) h-statistic for testing for the presence of serial correlation when a lagged dependent variable appears in the equation where the value shown is calculated after the appropriate transformation has been made. h fails when negative square roots are required as part of its formula and the Durbin-Watson statistic is shown instead. Durbin-Watson and h-statistics thus appear after the appropriate transformations, based on rho, have been undertaken. The estimate of rho, the first-order serial correlation coefficient, is shown as a test-statistic and is presented as combined evidence of the existence, or otherwise, of serial correlation. As mentioned, rho is derived by Maximum Likelihood methods and has been estimated jointly with the rest of the coefficients in the equation.

Table 6.4 presents results for store beef heifers. On the test statistics alone it provides a more complete description of the store purchasing decision with up to 87% of the variation in store beef heifer prices accounted for by the RHS variables.

Expected fatstock price in the risk equation is incorrectly signed, however, and this therefore casts doubt on the validity of the significance of its associated risk (R_{1t}^*). Because of the insignificance of the 'parent' expectation of the risk variable, the risk variable itself cannot stand alone on the grounds of its own significance. That is, the parent expectation (in this case, expected fatstock price) must be significant before we can accept the significance of its associated risk. If the farmer is unconcerned about

expected fatstock price (because of the coefficient's insignificance) then he can hardly be concerned with the risk of misestimating those expectations.

The influence of expected feed price and its associated risk is very well established in statistical terms and is correctly signed on a priori grounds. It suggests a large element of the store purchasing decision in the store beef heifers market is related to its expected cost structure. Indeed, the significance of the influence of expected feed price is further established in the estimate of the conventional equation although we should accept that its coefficient in this instance will be biased because of the absence of the corresponding risk variable (which we know to be a significant influence from the risk-equation).

The influence of the two feed variables (main expectation and its risk) in the store beef heifer equation corresponds with what is happening in the store beef steer sector. The links between the two markets have already been examined and it was suggested that the only difference (for the purposes of our own analysis) between them is that beef heifers may be used in the breeding herd. The results should, to the extent that heifers and steers are part of the same market, be mutually supportive which is what we find in the evidence on the coefficients of expected feed price and its associated risk in the two equations.

Expected covariance risk is insignificant. Even tentative conclusions about its influence cannot be offered (as we did in the beef steer sector) since the sign of expected fatstock price is confused on a priori grounds. Since expected fatstock price is a component of covariance risk then firm conclusions on the latter cannot be drawn because of the negative coefficient on the former.

The lagged dependent variable may be representative of a number of influences but not, as we have mentioned, of any implied Adaptive Expectations process (Sec. 6.4). The two should not be confused for the role of Adaptive Expectations is completely specified by the expectations variables themselves. This then leaves no theoretical grounds on which to assume that the lagged dependent variable is implicitly measuring adjustment rates on expectations (c.f. Sec. 2.4.2). In this instance, the lagged dependent variable is regarded as a partial adjustment of store price from last period's market relations. Thus, if last period's market relations determined last period's store price, then the lagged dependent variable implicitly carries with it influences of supply and may therefore tackle some of the problems of simultaneity in the demand equation that has been estimated.

Lagged dependent variables are always difficult to justify on economic grounds. They are invariably significant contributors to statistical explanation, but this may arise simply because of the autoregressive nature of time series: 1971's first-quarter store heifer price is bound to be correlated with 1971's second-quarter price. We can only say that if partial adjustment did not exist then there would be no role for the lagged dependent variable in the equations as they have been specified. Since the variable is statistically significant in a market in which immediate adjustment to all economic forces is extremely unlikely (at the very least, it takes 3 months to fatten a two-year old store beef heifer), then economic content may be inferred on these grounds.

Hay price is correctly signed but is insignificant. The far greater significance of the expected feed cost variable and its associated risk perhaps implies that there is little in the way of further explanation on the role of feeding sources required in store demand. This is despite the fact that hay price and expected feed price are determined by different processes. The relative significance of the latter indicates that it is artificial feed which is uppermost in the farmer's mind at the time a store beef heifer purchasing decision is made.

The implied aggregated risk variable is insignificant, but the major component of aggregated response appears to be positive; that is, risk-prone. This is not readily understandable in terms of its independently estimated components, R_{1t}^* and R_{t2}^* , and their components, FT_{1t}^* and FD_{2t}^* because of the incorrect sign of expected fatstock price. As a result of this the aggregated risk result cannot be trusted to produce much support for the measurement of risk on net profitability, in total.

An autocorrelation transformation has been undertaken on the store beef heifers equation which has been based on the assumption of first-order autocorrelation. The first-order autocorrelation coefficient, ρ , is shown and indicates that a significantly negative error-autoregression exists. Autoregressive ML methods have been used to estimate the equation (Harvey 1981 Sec. 7.1) whereby theoretically consistent estimates of the coefficients and standard errors in both risk and conventional equations have been derived.

The conventional counterpart to the risk-inclusive store beef heifers equation indicates a positive response of store price to expected fatstock price which is the opposite to the risk-equation result. We can only assume that since feed expectations and its associated risk are significant in the risk-inclusive equation that this sharpens the accuracy with which the other parameters are estimated. The conclusion is that expected fatstock price is insignificant, either way, and that the primary contribution to the analysis of store beef heifer demand is to illustrate the importance of expected feed costs and associated risk.

TABLE 6.5 REGRESSION ESTIMATES FOR STORE PIG DEMAND

	Risk Equation	Conventional Equation
Constant	-109667 (49865)	11.509 (3.264)
SC_{t-1}	0.562 (0.118)	0.499 (0.139)
FT_{1t}^*	0.199 (0.077)	0.098 (0.065)
FD_{2t}^*	-0.033 (0.023)	-0.041 (0.025)
R_{1t}^*	18621 (8466.1)	
R_{2t}^*	-0.047 (0.024)	
Cov_{12t}^*	-47384 (99940)	
LN_{t-1}	-0.005 (0.013)	0.381 (0.002)
T (Aggregated Risk)	1.093	
TEST STATISTICS:		
h	0.758	-0.694
F	20.735	16.957
R^2	0.759	0.618

Table 6.5 presents the strongest results in terms of statistical significance. All risk and expectations coefficients in the store pigs market are correctly signed from the reasoning given for the effects of official intervention in the market (Sec. 4.2.3). It is interesting to note the significance of the parameter estimates of risk and relate this to the traditional variability and uncertainty associated with pig production in general (the 'hog cycle').

The strength of the parameter estimates indicates that the lag structure on which all expectations in the store pig market ($P/E=1$ in all cases) accurately reflects the dynamic relations involved in pig fattening. Moreover, we have accurately specified the equation in terms of the components of marginal store profitability in that each one is statistically significant.

The interpretation of the results suggests that store pig fattening is subject to uncertainty as an elemental part of production. The fact that expected fatstock price risk is positive indicates a firm response to increases in price variations from their expected values. Variability in prices, it seems, is distinctly welcomed as a subjective phenomenon on which store pig purchasing decisions are based. The fatstock pig market is supported against falling prices, whilst an upper limit to price increases does not exist. The subjective effect of variability in fatstock prices is synonymously viewed as upward price mobility for purposes of store pig demand and may therefore be regarded as being associated with a higher mean value of fatstock prices from their average or support levels.

The size of the expected fatstock price risk coefficient (18621) implies that any element of variation in the scale of risk is immediately translated as a motive to purchase further stock. Recall, from the results in Table 6.2, that the adjustment coefficient on expected fatstock risk in the store pig market was extremely small ($0.4E-09$), but significant, which forces the scale of risk to become a constant. Hence, there can be no variation in fatstock risk. The subjective coefficient of risk (18621) then means that a constant level of subjective risk is added as a component of store pig demand. In other words, subjective fatstock risk is a significant, but constant, element of store demand.

The coefficient's large size, however, is a consequence of the fact that the scale of expected fatstock risk is a constant. Recall from the AE adjustment parameter results in Sec. 6.6.2 that the parameter for expected fatstock price risk was very small (0.4E-09) which results in expected risk becoming constant. This inevitably translates itself into a large coefficient because if dY/dX is the coefficient estimate of the effect of expected fatstock risk on store pig price then it is immediately obvious that:-

$$dY/dX \rightarrow \infty \quad \text{as} \quad dX \rightarrow 0$$

That is, dX (the change in expected fatstock pig price risk) is more or less zero because the underlying measure (the scale of risk) is constant.

The interpretation of constant subjective fatstock price risk is that pig farmers view the level of variability in the fatstock price in a constant manner. For all intents and purposes, subjective fatstock price risk will never alter the patterns of store pig demand, only contribute a constant amount to it.

This is clearly not the case with feed price risk which is significantly negative and which contributes to variations in store pig demand. The internal consistency of the equation (significant 'parent' expectations validate significant risk) indicates that feed risk inhibits purchasing of store pigs and simply reflects the role of feed costs in the industry (we emphasised this particular point in the pig market review, Sec. 3.6).

Aversity to variations in feed costs is also illustrated in the sign of the expected covariance risk coefficient which suggests that covariation between fatstock and feed prices is viewed in terms of a reduction of profitability per marginal store purchased. The insignificance of the result, however means that we cannot draw conclusions on a firm basis.

The implied aggregated risk variable is a disappointing result considering the significance of its components. A positive sign suggests fatstock price risk to be a more dominant influence on store purchasing than feed risk. The result, as it stands, provides support for the specification of net profitability risk for the marginal store in terms of fatstock and feed. The result is indicative of the potential confusion that a relatively more aggregated approach to the analysis of risk in store pig demand would produce.

A lagged dependent variable viewed in terms of partial adjustment indicates a wariness to base current store pig demand on immediate past store prices. This is illustrative of the importance of expectations. Pig farmers base their store purchasing decisions on the grounds of what is likely to happen to net profitability (i.e. expectations), not on what has already happened in terms of partial adjustment. In other words, pig feeding farmers rely more on their ability to predict prices to determine store demand than on the evidence of past store prices.

Alternatively, partial adjustment may be viewed as a consequence of prohibitive costs to change. These may be significant for the marginal store if, as we assume, the farmer is working near to his farm capacity, so that there is very little room to manoeuvre throughput levels. Capacity constraints may rule-out changes in store throughput because additional investment may be required in housing, for example, which cannot be immediately implemented, hence a partial adjustment figure for store pig demand of only 0.526 (risk equation).

Lagged livestock numbers is statistically insignificant and incorrectly signed in terms of a motivation to purchase additional stores: that is, as a demand variable. The variable is correctly signed if it is viewed as a supply influence in which case it will have an inverse relation with store price.

The conventional counterpart for store pig demand is much less robust than the risk-inclusive equation. All the variables are correctly signed with a noticeable change in the role played by lagged livestock numbers which is now significantly represented in its demand-role (discussed above).

The implication to be drawn of a comparison between the two equations is that, at the very least, the inclusion of risk significantly alters the pattern of store pig demand from the conventionally estimated equation; at most, the inclusion of risk 'sharpens' the parameter estimates of the expectations variables in terms of statistical significance which suggests that store pig demand is correctly specified in these terms.

TABLE 6.6 REGRESSION ESTIMATES FOR STORE SHEEP DEMAND

	Risk Equation	Conventional Equation
Constant	12.948 (2.946)	11.872 (1.751)
FT_{1t}^*	0.055 (0.026)	0.058 (0.023)
FD_{2t}^*	-0.6E-03 (0.026)	0.003 (0.026)
R_{1t}^*	-0.003 (0.006)	
R_{2t}^*	-0.005 (0.065)	
Cov_{12t}^*	0.9E-04 (0.2E-03)	
LN_{t-1}	-0.6E-03 (0.3E-03)	-0.6E-03 (0.2E-03)
Hay_t	-0.106 (0.032)	-0.104 (0.029)
T (Aggregated Risk)	-0.532	
TEST STATISTICS:		
DW	1.693	1.590
F	7.891	13.681
$\bar{R}^2$	0.529	0.514

The weakest results appear in the store sheep sector in Table 6.6. It is clear that the sector is not amenable to this type of analysis either in terms of investigating the motives for store purchasing or in terms of the specification of the functional form.

Perhaps the main reason why the results are inconclusive is that the store sheep market is not clearly defined in the sense that the store beef market is. Store sheep sales and purchases are not generally part of the production process as we have suggested in Sec. 3.7. In that section we intimated that the store sheep market exists because certain stock did not reach a physical condition to be sold as lambs with the rest of the flock, hence they are held over for sale as store at a later date. Consequently, the store sheep market may not be sufficiently regulated in terms of the existence of distinct market relations (supply and demand, and their determinants) which establish a meaningful market price. Meaningful is referred to in the context of being amenable to econometric analysis: if supply, demand and the market price are only weakly based on those aspects of sheep meat production that are likely to determine supply and demand, then there cannot be much hope of statistically measuring these influences.

The only significant result in the risk and conventional demand equations in the store sheep sector is the coefficient on expected fatstock price. Since fatstock price is a definite sale point in the mutton and lamb production process then the expectation concerning fatstock price is likely to be well established. This is because the fatstock market is well regulated in terms of a definite supply and demand structure from which a market price is readily observed.

The implied aggregated risk coefficient is no more informative than the estimates of subjective risk that comprise it. It is negative (hence implying overall risk aversity to variations in net profitability), but is too statistically insignificant to be of any analytical use.

Despite the general insignificance of the two store sheep demand equations (risk and conventional) the RHS variables do manage to explain up to 50% of the variation in the dependent variable, as evidenced by R^2 . This is symptomatic of multicollinearity which may indicate that a respecification of the functional form may yield further results. Although various forms have been tried, there is little room to change variables used and retain the store sheep market within the context of an analysis of expectations and risk. To this end, the results have been presented as they appeared so that comparisons may be made across store markets.

TABLE 6 .7 REGRESSION ESTIMATES OF STORE DAIRY DEMAND

	Risk Equation	Conventional Equation
Constant	132.417 (47.051)	157.632 (70.894)
FT_{1t}^*	0.017 (0.119)	-0.019 (0.046)
FD_{2t}^*	-0.473 (0.221)	-0.862 (0.417)
DC_{3t}^*	-0.015 (0.359)	-0.666 (0.277)
R_{1t}^*	-0.002 (0.002)	
R_{2t}^*	-0.2E-03 (0.2E-03)	
R_{3t}^*	-0.534 (0.472)	
Cov_{12t}^*	0.004 (0.002)	
Cov_{13t}^*	0.1E-03 (0.6E-04)	
Cov_{23t}^*	0.3E-03 (0.1E-03)	
LN_{t-1}	0.026 (0.077)	0.069 (0.123)
Hay_t	-1.319 (0.277)	-1.599 (0.589)
τ (Aggregated Risk)	-1.352	

TEST STATISTICS:

$\hat{\rho}$		0.609 (0.131)
DW	1.703	2.023
F	19.389	4.421
$-2R$	0.825	0.306

Finally, Table 6.7 presents the results for store dairy down-calver demand. The modelling of demand in this sector is subject to a number of assumptions concerning the lag structures in the expectations processes that we have previously discussed (Sec. 6.5.3). We suggested that approximations had to be made with respect to, for example, the date of sale of the purchased store into another dairy herd (with expected dairy cow price then being relevant as an aspect of calculating expected store profitability). The imposition of these assumptions which are, of necessity, only average representations of conditions in the store dairy market, may have resulted in the generally weak statistical estimates of the components of store demand.

Only expected feed price has any statistical significance in the risk equation whilst expected dairy cow price is incorrectly signed. None of the risk variables are significant although two of their covariance counterparts are. This suggests that the decomposition of risk into components relating to expected fatstock, feed and dairy cow price is incorrect. Some combination will probably be more relevant. Therefore, if we examine the significance of the implied aggregated risk variable in Table 6.7 a reasonably significant (at 80%) risk-averse situation is observed. This indicates the purchasers of store dairy replacement stock are averse to variations in net profitability and that this will be reflected in a reduction of store demand should variability increase. Too much meaning cannot be attached to this, however, because of the confused signs of the main expectations variables. It is suspected that

the structure of the equation, or the hypothesised lag structure which generates expectations, suffers from over simplification. Different, and more complex, lag structures have been investigated but none have been successful.

The failure of our analysis in the store dairy market is likely to be a result of using discrete time when the expected profitability of purchased stores rests on income flows. When a store replacement is purchased and milk begins to be produced then the revenue from milk sales is more or less continuous. To approximate marginal store profitability on the basis of fatstock, dairy cow, and feed prices, plus their associated risks, is perhaps requiring too much of the model's explanatory power. There is nothing that can reasonably be done about this given the quality of the data that is available.

6.6.4 Elasticity Estimates

This section presents the final results of the analysis of store demand using the AE hypothesis where coefficient estimates of the equations 6.1 and 6.3 for all markets are turned into elasticities calculated at the mean. Data means used are listed in App. 6.

TABLE 6.8 ELASTICITIES FOR STORE DEMAND EQUATIONS. ESTIMATED AT THE MEAN

	<u>Steers</u>		<u>Heifers</u>		<u>Pigs</u>		<u>Sheep</u>		<u>Dairy</u>	
	R	C	R	C	R	C	R	C	R	C
SC _{t-1}			0.952	0.905	0.526	0.499				
FT _{1t} *	0.489	0.851	-0.265	0.037	0.662	0.217	0.343	0.362	0.002	-0.024
FD _{2t} *	-0.196	-0.236	-0.174	-0.3E-04	-0.275	-0.308	-0.004	0.002	-0.465	-0.322
DC _{3t} *									-0.016	-0.702
R _{1t} *	0.160		0.055		12213		-0.007		-0.022	
R _{2t} *	-0.220		-0.065		-0.024		-0.002		-0.152	
R _{3t} *									-0.083	
Cov _{12t} *	0.002		0.004		-0.9E-03		0.003		18.15	
Cov _{13t} *									1.036	
Cov _{23t} *									0.009	
LN _{t-1}	0.291	0.299			1.002	-0.522	-0.122	-0.121	0.087	0.020
Hay _t	-0.064	-0.006	-0.028	0.011			-0.195	-0.191	-0.328	-0.390

R = Risk Equation. C = Conventional Equation

The evidence on elasticities presented in Table 6.8 should be strictly interpreted in relation to the statistical significance of their related coefficient estimates. We shall not discuss the results in detail since this information is already contained in the analysis of the corresponding models' coefficients. A broader overview of response will be provided.

A comparison of elasticities between risk and conventional estimates in some markets suggests differing responses dependent on the inclusion of risk variables. This is particularly noticeable in the elasticities for expected fatstock and feed prices in store steers, store sheep and store dairy equations, and in elasticities for livestock numbers in the store sheep and dairy markets. In these cases greater response was found when risk was omitted from the equations. On the other hand, smaller elasticity estimates were found in the conventional estimates of expected fat and feed prices in the store heifer equation, in expected fat price in store pigs and in lagged livestock numbers in steers and pigs.

The indications of these results suggests, when risk variables are significant in the risk equations, that better (i.e. more accurate) estimates of other parameters have been found. This was in fact a primary motivation of Traill's (1978) study of econometric risk variables, and our own results support his conclusion that the exclusion of risk, when it is relevant, will bias remaining parameter estimates.

The other features of the elasticity estimates suggest that response, in most cases, is sizeable. Only a few estimates provide evidence of more than proportional response (elasticity greater than unity) and it is these results to which we now turn.

The main example of large response is in the estimate for the elasticity of expected fatstock price risk against store price in the pig market. We have previously noted that the risk adjustment coefficient in the AE mechanism which determines the changes in the scale of risk is very small ($0.4E-09$), but quite significant ($SE=0.1E-09$, $t=4.0$). The effect of this is to make the scale of expected risk a constant. This cannot, by itself, determine the responsiveness of fatstock risk in the store pig market as that is determined by the coefficient estimate.

However, it will undeniably influence what elasticity result will be found because response will then be estimated against a background of constant risk, and subjective risk (the resulting coefficient estimate) will incorporate this particular feature in its own estimate.

The elasticity estimate of fatstock price risk against store pig price is large (12212), suggesting that pig feeders will take every opportunity to make extra profit when it becomes available, as indicated by increasing variability in fatstock price risk. The scale of the response is purely a consequence of the size of its underlying coefficient estimate. As previously mentioned (Sec. 6.6.3), if Y can be regarded as the dependent variable and X as fatstock pig price risk then the elasticity of 12213 is defined as

$$\eta = dY/dX \cdot X / Y$$

But we have already seen that since X is virtually a constant that

$$dY/dX \rightarrow \infty \quad \text{as} \quad dX \rightarrow 0 \quad \text{hence as} \quad dY/dX \rightarrow \infty \quad \text{then} \quad \eta \rightarrow \infty$$

which explains the scale of the elasticity estimate. This elasticity provides further evidence of the inherent instability of the market. Thus, risk may be evaluated as having a constant level but, in relation to store pig price,

it determines a large measure of responsiveness in store demand in general.

Dairy market covariance risk between expected fatstock and feed prices and between expected fatstock and dairy prices are also fairly responsive. However, it must be accepted that model specification is particularly difficult in this market and that this must qualify any results we obtain.

Finally, it is interesting to note the size of some risk elasticity estimates in relation to their 'parent' expectations elasticity estimates. For example, the expected feed price risk elasticity in the store beef steers market (-0.220) is 100% larger than its parent elasticity (-0.196). This indicates a strong element of risk aversity to changing feed prices from their expected values. The corresponding result in the store beef heifer market is only 37% (-0.174 to -0.065) suggesting that feed price risk is rather less influential in determining store purchasing decisions. This may arise because of the fact that heifers have two outlets: beef sale or entering the breeding herd. Consequently, feed risk may be spread between the two.

Similar figures of relative response (feed price to feed price risk) may be observed in the sheep and dairy markets (50% and 32%, respectively).

The corresponding results for fatstock prices show that risk response relative to fatstock price response is generally smaller (in absolute terms: 33%, 20% and 2% for steers, heifers, and sheep respectively). The results for pigs and fatstock price in the dairy equation are much larger. The latter, however, cannot be relied upon since its underlying coefficient estimates are insignificant. Relative fatstock price response in the pig market is enormous. This is due to the constant scale of risk underlying expectations behaviour which has already been mentioned. The accuracy of the fatstock price risk elasticity estimate cannot also be relied upon because response to

variability is so strong that to put a unique estimate on it may be misleading. What we can be sure of is that risk response certainly exists and that it is more than proportional to changes in store pig prices.

6.7 Conclusions

We have developed an econometric method which has tackled model specification of risk response in an Adaptive Expectations framework in two ways. Firstly, it is a consistent and optimal approach in that freely estimated adjustment parameters are derived so that values for unobservable expectations may be generated. The exception is covariance risk which was constrained to be in accordance with the freely estimated risk adjustment parameters (Sec. 6.5.1). The details of the estimation procedure have been fully outlined and indicated the necessity that the number of assumptions in the econometric method (and hence the number of constraints imposed on the system) should be kept to a minimum. The search for optimal and consistent adjustment parameters to define expectations and risk is then clearly data-orientated and the analytical approach is designed not to manipulate information for the sake of model simplicity.

Secondly, the use of the P/E ratio precludes the requirement for the presence of complicating lag structures in the main equations (6.1 and 6.3). The lag structures are placed in the first stage of the two stage estimation procedure where the Adaptive Expectations adjustment coefficients are estimated.

In order to make the results comparable with other econometric investigations or risk we investigated how the components of risk could be aggregated and its statistical significance measured. This analysis rested on establishing exactly what theoretical relations exist between the coefficients on the main expectations variables in equations 6.1 and 6.3 and their associated risk

coefficients. We derived a workable measure using a basic statistical theorem (equation 6.2) and established the significance of aggregated risk from this result.

The main results indicated in what markets risk was an important feature of the store purchasing decision process. Risk was found to be particularly relevant in store pigs, beef heifers and beef steers markets, but less reliable results were found in the store dairy and sheep markets. This information was then presented in the form of elasticity estimates to suggest the degree of response of store demand to risk and to illustrate why conventional (risk-exclusive) estimates may be misleading.

The analysis of this chapter is extended in Chapter 7 which examines the nature of store trading and risk perception in the context of a simultaneous model.

CHAPTER 7

RISK, RATIONAL EXPECTATIONS AND THE ESTIMATION OF STRUCTURAL STORE MARKET MODELS

7.1 Introduction

In this chapter we shall examine the role of risk within the context of a dynamic and simultaneous model for each of four store markets. The concept of 'moving risk' is employed as it was in Chapter 6 but we shall now define how risk 'moves' by the Rational Expectations (RE) hypothesis.

It was shown in Chapter 2 exactly how it is dependent upon an economic model which is assumed to describe store market mechanisms. In Chapter 3 these mechanisms were outlined and the biological and economic structures in each store market were described. The variance-based measure of risk will be used in relation to RE and the justification for this assumption has been fully investigated in Chapter 4. It was shown what assumptions are necessary concerning the form of the individual utility functions for the variance measure to have a theoretical base. The marginal animal approach was then examined and showed how equation specification could be simplified in terms of a price-only framework. Appropriate aggregation rules or assumptions then facilitated a market analysis of risk.

In essence, a more general analytical approach is employed in this chapter and it will be seen that the methods and conclusions are a synthesis of all that has been previously explained: from describing how expectations formation interacts with risk perception, to illustrating what production processes are involved in the various store markets, by showing what theoretical assumptions are necessary for our conclusions to be meaningful and in incorporating some of the results already established in relation to the nature of store demand.

7.2 Variable Definitions and Date

The notation of Chapter 6 (Sec. 6.2) is used again. Additional variables are:-

Q_{St} = Store supply (numbers)

Q_{Dt} = Store demand (numbers)

SC_{4t}^* = Expected store price

R_{4t}^* = Expected risk associated with expected store price

I_t = Store imports

TS_t = Total slaughterings of animals

DI_t = Disposable income

IM_t = Imports of beef, pigmeat or mutton and lamb
(to be interpreted in context)

$BSUK_t$ = UK breeding stock

MB_t = Milk/Beef Price Ratio

Again, as in Sec. 6.2, all variables should be understood in context. Exactly what data was used for each variable and for each market is listed in App. 6.

7.3 Definition of Risk

We use the definition of risk outlined in Sec. 6.3. The 'moving component' of risk, however, is now based on the RE hypothesis. It may be worth re-reading Sec. 6.3 at this juncture.

7.4 Modelling Principles

The investigation is extended from the demand analysis of Chapter 6 to a full simultaneous and dynamic framework where we have more scope to develop our ideas concerning the structure of economic relations in the store markets.

Four models are estimated: one each for beef steers, beef heifers, pigs and sheep. It was decided on the grounds of the results of Chapter 6 that the dairy market could not be usefully extended in this more complex approach because the biological lag structures in dairying preclude estimation with relatively small data sets. Moreover, problems with specifying the lag structures in the dairy sector were suggested as the cause of the failure of the statistically weak results of Chapter 6 and this difficulty could only be exacerbated in a simultaneous model. Although the results of Chapter 6 were only partially successful using discrete time it was felt that simultaneous, discrete-time modelling would not be feasible for the dairy sector. Consequently, the store dairy market is not examined.

7.4.1 General Model Structure

The remaining four models are estimated employing the hypothesis of Rational Expectations to define 'moving risk'. We shall use the notation $E[X_t/I_{t-1}] = X_t^*$ interchangeably in this section to discuss the model's dynamic structure where expectations in a dynamic context are defined in terms of when information is available (Sec. 2.4.1). A general structure for all models is

$$Q_{st} = \beta_{10} + \beta_{11}E\{SC_t/I_{t-1}\} + \beta_{12}E\{R_{4t}/I_{t-1}\} + \beta_{13}FD_t \\ + \beta_{14}MB_t + \beta_{15}BSUK_{t-1} + \beta_{16}I_t + \epsilon_{1t} \quad (7.1)$$

$$Q_{dt} = \beta_{20} + \beta_{21}SC_t + \beta_{22}E\{FT_{t+j}/I_t\} + \beta_{23}E\{FD_{t+j}/I_t\} \\ + \beta_{24}E\{R_{1t+j}/I_t\} + \beta_{25}E\{R_{2t+j}/I_t\} + \epsilon_{2t} \quad (7.2) \\ j = 1, 2$$

$$I_t = \beta_{30} + \beta_{31}FT_t + \epsilon_{3t} \quad (7.3)$$

$$FT_t = \beta_{40} + \beta_{41}TS_t + \beta_{42}DI_t + \beta_{43}IM_t + \epsilon_{4t} \quad (7.4)$$

$$FD_t = \beta_{50} + \beta_{51}B_t + \beta_{52}W_t + \beta_{53}HAY_t + \epsilon_{5t} \quad (7.5)$$

$$Q_{st} \equiv Q_{dt} \quad (7.6)$$

Equations 7.1 - 7.5 and the identity 7.6 represent a 'starting point' from which the discussion of model structure will begin since none of the models presented for examining risk and expectations are estimated exactly in this form. This is the easiest point from which to depart because it embodies the fundamental ideas concerning the economic structure of the store markets. Subsequent modifications are due to RE solution and econometric requirements and will be fully discussed in context.

It is difficult to discuss the economic motivation for each equation in detail without referring to the system as a whole. Justification of the model structure is therefore arbitrarily split into two: we discuss each equation first and then turn to what the system is describing in terms of the dynamic and simultaneous linkages.

Equation 7.1 is the store supply equation. The only uncertain decision-variables influencing the number of stores sold onto the market in each quarter

are assumed to be store price and its associated risk.

The expectation of store price is made on the basis of information which is only available up until the end of period $t-1$; that is, conditional on information I_{t-1} . Thus the farmer will make a decision concerning how many stores to breed in period $t-1$ for sale in period t . The relation between the conditional expectation in $E\{SC_t \mid I_{t-1}\}$ and the dependent variable, Q_{St} , must always be based on two different time-periods ($t-1$ and t , respectively) if the equation is in any way to represent how long it takes the breeding farmer to produce a store ready for sale. The difference in the time-periods represents the biological lag structure of store production between the motive to produce, SC , and actual store supply, Q_{St} . The concept of the time-difference relation will also be used in the store demand equation.

Associated with any expectation is its concomitant risk of misestimating expectations. Expected risk must be based on the same time-difference relation as its parent expectation otherwise the former would not represent uncertainty in the latter.

The level of store supply, or in marginal animal terms the decision to sell or not sell the marginal store, is initially set by expected store prices and associated risk. These embody all past available information on how store prices were established; if not, then expectations defined in the supply equation would not be Rational. Recall that a rational expectation of a variable will use all available information, not just a weighted combination of past actual values of itself, as in the AE case.

The profitability of each (marginal) store sale will also be considered in relation to actual feedgrain prices where a rise in this price may force the farmer to offload his stock onto the market and vice versa should the price fall. We would therefore expect a positive relation between feedgrain price and store supply.

The effect of the lagged value of the breeding stock is to establish what influence future generations of stores has on current store supplying decisions. That is, store supply in period t is assumed to be in direct proportion to the breeding herd that produced it roughly three months (one quarter) before. If the breeding stock rises then so will store supply, and vice versa for a fall.

The use of BSUK is the correct specification of the influence of potential future supply of stores in a simultaneous framework. The purpose of the breeding stock (and livestock numbers in the demand analysis of Chapter 6) is to account for trend movements in the size of store market throughput and therefore isolate the effects of expectations and risk variables on the dependent variable. Thus, in Chapter 6, lagged livestock numbers indicated the effect of potential store supply on store price through a reduced-form demand equation. In the more general analysis of Chapter 7 potential supply must be accounted for through the influence of the breeding stock on the dependent variable. Since BSUK is definitionally a store supply variable then it must appear in the supply equation when the dependent variable is measured as the quantity of stores supplied and not store price as in Chapter 6.

The breeding stock is expected to have a greater influence on store supply in some markets than in others. Recall that the pig breeding herd, for example, was central to Government policy in the sector prior to 1973 because its size was relatively malleable (Sec. 3.6.1). It is this type of response that we attempt to measure in relation to store supply in general.

The level of store imports is an addition to store supply and must, by definition, be included in the store supply equation. It is an endogenous variable in itself and will be examined in turn.

The milk/beef price ratio (MB) enters the store supply equations for beef steers and heifers only. It represents a link with the dairy sector which is assumed to have consequences for both beef markets. Store beef supply not only emanates from traditional beef producers but will also feature as part of some mixed dairy production systems. Therefore, the milk/beef price ratio will reflect the relative profitability of the dairy and beef systems. Should the ratio fall the store beef sale of animals will take place and hence store beef supply will increase. The converse is true for an increase in the ratio, thus, the expected sign of the coefficient on MB is negative.

The demand equation 7.3 has more or less the same structure as the demand equations estimated in Chapter 6. It represents the calculation of the 'feeder's margin' for the marginal store purchase and in that sense is no different from what has already been explained in Chapter 6 (Sec. 6.4). However, three aspects of the demand equation in this chapter distinguish it from the analysis of Chapter 6.

Firstly, quantity demanded (Q_{Dt}) is the dependent variable. This is the correct specification in a simultaneous framework (as opposed to a single equation framework) since it is basically price that determines quantity supplied or demanded in any competitive market. The supply and demand equations (7.1 and 7.2) are therefore set equal to one another by the identity 7.6. This then establishes store price (SC_t) as the variable for which the market solves.

Store price is determined, by the interactions of supply and demand, in period t and enters the demand equation specifically as an explanatory variable because it represents the buying-in price of store stock.

Secondly, the lead structure $(t+j)$ upon which forward expectations for FT_{1t} , FD_{2t} , R_{1t} and R_{2t} are defined is not set simply to $j=1$. This arises because, for the store purchaser, information is available up until period t . That is, for decision purposes, the store purchaser will have available current market information. The correct specification of expectations in a simultaneous framework must then be based on how long it takes to fatten a purchased store from period t . For a pig it is typically one quarter, hence $j=1$. For a yearling beef store (steers and heifers) it may be two quarters, hence $j=2$. And for sheep it will be one quarter, hence $j=1$. These are the lag structures we will use and, in terms of model motivation, have already been discussed in Sec. 6.5.3.

The third feature of the RE store demand equation which differentiates it from its AE counterpart is the omission of covariance risk. These are left out on empirical grounds because covariance risk was not found to be generally significant in the demand equations estimated for the beef, pigs and sheep sectors estimated in Chapter 6. This result accords with Just's (1974) conclusion that covariance risk is not a significant feature of risk response. In addition, covariance is omitted to ease some econometric difficulties and to keep the simultaneous system as simple, but as representative, as possible.

The store imports equation 7.3 illustrates the view that their level is primarily demand-determined. Imports represent the extent to which store suppliers fail to meet the requirements of the feeders. Evidence for this is to be found in Murray (1931) and Slattery (1966) who suggest that a main determinant of the level of imported stores are the returns to fattening: the feeder's margin. Hence, in the equation 7.3 actual fatstock price is the only explanatory variable. It is regarded as a sufficient explanation of the motives for importing stores in a marginal animal framework.

Fatstock price in equation 7.4 is established as a function of supply and demand influences which are related to the retail-end of meat production. Thus, total slaughterings (TS_t) represents domestic supply of meat onto the market whilst the import of meat (IM_t) represent foreign supply. In that respect, $TS + IM$ is a measure of the total supply of meat onto the market.

The demand-side is represented by disposable income (DI_t). This is only a very general measure of demand which has been chosen to keep the simultaneous system as simple as possible. We have to, at some point, decide where the simultaneous influences stop and the exogenous influences begin. Any standard econometrics textbook begins its discussion on the identification of simultaneous systems by outlining the importance of exogenous influences. Exogenous variables provide the 'movement' in the system from which the parameters of the endogenous variables may be estimated. Endogenous variables have no meaning without the exogenous processes that define them.

Disposable income, along with total slaughterings and the imports of meat, represent some of the exogenous processes which determine the rest of the model. In order to keep the model to manageable proportions we have to assume that disposable income, etc., are in fact exogenous so that we can exclude estimation of further equations. It is by no means clear in the econometric literature what is meant by 'exogeneity' (Engle, et al (1983)) since no definitive measure has been established.

What is generally accepted as the meaning of 'exogeneity' is that such variables are determined by influences which are not a part of the model to be estimated; that is, 'outside' the system. This view is accepted here and, hence, exogenous variables are used to 'close' the equation system in the sense that the equations we do specify are sufficient explanations of the endogenous variables that remain.

The feedgrain price equation is also 'closed' by three exogenous processes: barley price, wheat price and hay price. These elements are assumed to exemplify the supply and demand conditions in the feed market which are independent to our own equation system and which have a bearing, through their relations to feedgrain price, on the store markets.

The concept of the exogenous variables 'closing down' the equation system will become clear in a discussion of the dynamic structure of the system to which we now turn.

We have structured the store markets as components of a wider vertically related production process. Vertical structures only ever exist when a production process can be sub-divided into its component parts. In this way different producers can specialise in parts of the process at which they are, given available resources, most efficient. Markets then arise in a vertically structured industry to align supply and demand of the components of the production process. At a fundamental level, this action of market creation serves to join the components into one production process. A chain of markets which are successively related then emerges.

This is precisely how store markets operate: an animal is reared and sold in the store market where it is bought and fed to be made saleable in the fatstock market. In this market it is sold under conditions which reflect a broad meat supply and demand relations; that is, the fatstock market has its own determinants of supply and demand.

The whole vertical system (for $j=2$) is only based over three quarters. That is, the rearing decision is made in period $t-1$. The store is sold and purchased in period t . It then takes two periods (t to $t+2$) to feed the animal for the fatstock market.

The main dynamic influences (all those variables with time subscripts not equal to t) arise from the demand equation. In this equation lead values ($t+j$, $j=1,2$) occur on the expectations variables to reflect the fact that fatstock and feedgrain markets have an influence on demand but only through expectations which are made for the time when store stock are ready for sale as fatstock. That is, if the store is purchased in period t , then the fattened animal will not be ready for sale until period $t+2$ in the beef markets.

A diagrammatic illustration of the simultaneous and dynamic structure of the models has already been given in figure 4.1 of Chapter 4. This basic reasoning will be used throughout this chapter although modifications to the equation system will be made on the grounds of explanations to follow.

7.4.2 Autocorrelated Errors in RE Systems

The problems of simultaneity and autocorrelated errors in econometric estimation are simple enough tasks to deal with by themselves but pose significant problems when combined. The usual approach to this difficulty is to deal with one and ignore the other. Goldfield and Quandt (1972) cite the Wharton (Evans and Klein 1968) and Brookings (Duesenberry et al 1965) econometric models as examples.

We have noted in Sec. 2.4.3 that if autocorrelation exists in a simultaneous RE system, and if farmers have some knowledge of the structure of autocorrelated errors, then it is rational for the farmers to use this information to form Rational Expectations. In other words, if autocorrelated errors occur then we cannot claim to have a RE solution until something is done about it.

Autocorrelation and RE solutions are incompatible because the former implies model misspecification. Since RE is derived from the structure of a known model then the existence of autocorrelated errors means that the RE derived from the model cannot be correct. 'Correctness' is here defined as the true economic environment.

It has been emphasised in Sec. 2.4.3 that model specification must be complete in order to establish a RE solution. If it is not complete then we cannot, by definition, have a RE solution. Since autocorrelated errors may arise as a consequence of an incomplete model then we must establish exactly what error structure exists.

This is a relatively simple task in RE models, in theory, despite their ostensibly complex solution methods. We refer back to the concept of 'over-lapping' discussed in Sec. 2.4.3 and represented in equations 2.14 to 2.15. This refers to the fact, noted by Shiller (1978), that forecast errors are serially uncorrelated but not necessarily serially independent. That is, even though we may not have knowledge of the error structure, ex ante, it may arise as an autocorrelation, ex post (ex ante: before estimation; ex post: after estimation).

We may therefore expect autocorrelation to arise given the nature of forward expectations which may or may not result in over-lapping. If autocorrelation does arise then it must be accounted for, either by specifying a different lag structure and/or by transforming the equation system by well-known methods to establish independent errors (Hendry 1971). One is neither a complete substitute for the other and both clearly rest on assumptions concerning the error structure (first, second, third degree autocorrelation etc.).

We account for the existence of autocorrelated errors by specifying additional lag structures and then examine if this procedure has been successful in eliminating autocorrelation.

The autocorrelation example illustrated in Sec. 2.4.3 (equations 2.14 - 2.15) showed that for a two-period forward expectations that second-degree autocorrelation may arise. The appropriate transformation, or additional lag structure, would then be based on this result. Similarly, a one-period forward expectation may produce first-order autocorrelation and this then indicates what transformation should be undertaken.

In the case of the re-specification of the dynamic structure, the dependent or endogenous variable then acts as an additional lag or lags in the equation. The imposition of these is not undertaken in an ad hoc manner, however, since it will be seen that some equations have been lagged by their dependent variables whilst others have not. There are important reasons for this which explains the existence of additional lags consequent upon the dynamic or recursive links between the equations.

The equation structure of any economic system will indicate (and should indicate if the model is reasonably accurate) how each equation determines the others in the system. The simultaneous relations specify which economic quantities must be determined before the rest of the system can be solved. Thus, in the supply equation 7.1, BSUK (UK Breeding Stock) is lagged by one-quarter in relation to the dependent variable Q_{St} (store supply) indicating that BSUK must be known before store supply can be set. This analysis is then easily extended to endogenous variables. The implication now is that the equation specifying some endogenous variable must be determined before the rest of the system can be defined.

Various iterative simultaneous solution methods (Gauss-Seidal, etc.) provide insight into how the equation structure operates. This is achieved by an examination of the iterative order in which the equations are solved (Holden et al 1982 Sec. 2.3 and App. A2). The mechanism which establishes

the order in which equations may be solved is that those equations which are not influenced by any others are solved first. A value is then found (i.e. 'predicted') for its endogenous variable which then acts as the value for the variable as it appears in the other equations. The first equation may be specified in terms of exogenous processes (although this is by no means necessary) for a clear and definite start to the solution phase to be identified.

Thus, turning to our own equation system it is clear that the feedgrain and feedstock markets solve first since they are presented in terms of exogenous processes only. As both are equivalently defined on this basis it is arbitrary which one is chosen as the first equation to be solved. In all solutions to follow the feedgrain market is cleared (solved) first before the fatstock market clears.

Once solved, the predicted value of feedgrain price is found and this is then inserted into the supply equation. Fatstock price is next solved and the predicted value of this inserted into the imports equation which then enables that equation to be solved. The predicted value of imports are then inserted into the supply equation which can then be solved since no other endogenous influences are operating. Once the predicted value for store supply is found then, by the identity between store supply and demand in 7.6, store price is established.

This explanation is the standard routine whereby systems of equations are solved and estimated. Full Information Maximum Likelihood, Three Stage Least Squares, Seemingly Unrelated Regressions, Nonlinear Two Stage Least Squares, etc., all use variants on this method to establish iterative values of the parameters. But this essentially mathematical method provides insights into the model structure which we shall use to define additional lag structures consequent upon the existence of autocorrelation. Thus, our equation system is solved in the following order:

Feedgrain Price:	FD
Fatstock Price :	FT
Store Imports :	I
Store Supply :	Q_S
Store Demand :	Q_D

This accords with reasoning on how store markets should be structured and follows the diagrammatic representation of the system in Figure 4.2.

The equation ordering methods then indicate in what manner a lag structure may be imposed on the system to tackle the problem of autocorrelation. Lagged dependent variables appear in the equations to be solved first and their influence on parameter variances is examined. If better (i.e. more efficient) estimates are obtained by successively defining additional lags on the equations on the basis of the ordering outlined above then this task is undertaken. What is presented below are the most efficient estimates derived from this method. In fact, by the time the first three or four equations have had additional lag structures imposed then this appears to produce the best results.

If autocorrelation persists (by an examination of the Likelihood Ratio Statistic; c.f. any advanced textbook, Harvey 1981) then the usual transformation is undertaken (Hendry 1971) where first and second-order autoregressive residuals are assumed to comply with one or two-period forward expectations, respectively.

7.5 Rational Expectations and the Theoretical Implications for Risk

Subjective risk has been defined as

$$E\{(X - E(X))\}^2$$

which is also an explanation of 'moving risk' when, as we do, define $E(X)$ on the basis of an expectations mechanism.

When risk is defined in this manner it is immediately seen as a fundamental measure of the mistakes an individual may make concerning the formation of his expectation of the variable X .

Subjective risk measures the deviation of expectations from actual values of the variable X , or can be equivalently viewed as an error of forecasting. However, it is only an expected forecast error which reflects the associated risk of making such errors the information on which has been derived from past experience (recall that all expectations are conditional on previously available information otherwise the expectation would not be required). But this information in a RE framework represents all the available knowledge of events surrounding subjective risk, or any rational expected variable, viz.

$$E\{(X_t \mid I_{t-1})\}$$

If, by definition, I_{t-1} represents the entire information set in a RE model then no more information is available to the farmer to change his opinion on what value the expectation should take; that is, he can have no possible reason to change his mind if he uses all the available information. In terms of the definition of subjective risk:-

$$E\{(X - E(X))^2\}$$

the deviation which is part of the formula must therefore be random. If it were not random then it would be systematic. If it is systematic then it must have a structure which rational farmers would employ in their forecasts. Hence, by definition the deviation must be random.

If this is true then the subjective measure of risk must also be random. The conclusion is apparent: subjective risk in a RE framework is exogenous. If subjective risk is not exogenous then we cannot claim to have a RE solution because we are not using all the available information.

If this result is compared with the AE hypothesis then we see that no such claim to exogenous subjective risk can be made because the AE hypothesis does not use all the available information, only past actual values of the variable to be predicted. We know from Sec. 2.4.2 that the AE hypothesis is really an assertion that current expectations are based on an extrapolation of weighted averages of past actual prices, say. Prices may or may not contain all the information which is pertinent to the formation of a price expectation. Hence, the most that can be said about moving risk based on the AE mechanism is that risk may or may not be exogenous. There is no way of being completely sure, unlike the RE system where risk is tautologically exogenous.

7.6 Analytical Methods

This section presents the method by which the simultaneous model is solved in a RE sense. It will be seen to be a much simpler method than was illustrated in the RE example of equations 2.16 and 2.17 in Sec. 2.4.3. It will also be seen to be far simpler than the analytical approach to deriving optimal adaptive expectations (Sec. 6.5).

7.6.1 The Rational Expectations Solution

We have already mentioned that RE systems may be solved in two ways: the 'algebraic approach', which was illustrated in Sec. 2.4.3, and the 'numerical approach', which was mentioned in the same section. It is the purpose of this section to outline why the numerical approach is superior to the algebraic approach and to outline what implications the adoption of the numerical approach has for the stability and uniqueness problems encountered in RE models.

7.6.1.1 Numerical Method

The algebraic approach to solving RE models was seen to be fairly complicated in relation to the simple equation structure to be solved. The requirement that expectations be based on an economic model meant deriving algebraic expressions which represented a RE for a particular variable. It is these expressions which make this solution procedure complicated. Furthermore, since a growing number of economic models are nonlinear (including our own; c.f. variance measure of risk) then algebraic solutions to such systems are unreliable (expectations of nonlinear functions are not guaranteed to be simple derivable combinations of functions of the expectations of their components, Goldfield and Quandt 1972).

To overcome these difficulties numerical methods for solving RE models may be used. When we refer to 'solving' RE systems it should be taken to mean that, in a way to be demonstrated, expectations are derived from the model which may be said to be 'Rational'. Standard simultaneous methods are then used to derive estimates of the structural parameters. The former will hereafter be referred to as 'solving' and the latter as 'estimation'.

Expectations are derived from an economic model by model prediction methods. That is, period by period predictions are derived or simulated from the estimated model which are, by definition, the model's solution for expectations of the endogenous variables.

Model prediction then provides estimates of the values of expectations. However, since the model is composed of expectations variables as explanatory variables then we must first guess as to what values these expectations should have before the solution phase may begin. Only after expectations have been iteratively altered and which satisfy a suitable convergence criterion may these expectations be called Rational.

The purpose of the iterative adjustment of expectations is to purge the expectations variables that enter the equation system of their endogeneity.

In other words, to find values for the expectations variables (such as FT_{1t+j}^* , FD_{2t+j}^* , R_{1t+j}^* , etc.) which can then be used to derive structural parameter estimates which are simultaneously unbiased.

Expectations are iteratively adjusted from their initial (guessed) values so that the values of expectations that enter as explanatory variables in the equation system become equal to the model predictions for the endogenous variable expectations. That is, expectations that enter as explanatory variables are the same for which the model would solve. In this way the expectations so derived change little from one iteration to the next and hence they become expectations which are based on the economic model. If the economic model represents all the available information on the structure of economic relations then these expectations are Rational. The point at when expectations that enter as explanatory variables become the same as the model's solution then defines, along with the model's solution being in reasonable proximity to their actual equivalents, the convergence criterion for establishing RE.

The validity of the solution procedure and the convergence criterion is then easily established from the definition of RE: expectations should mirror how the model would solve for expectations. That is, explanatory expectations and model predictions should be identical. This particular solution method has now a burgeoning pedigree since increasingly complex computer software has made the construction of large nonlinear simultaneous models simple to manage (Minford 1978 b, Anderson 1979, Beenstock and Holly 1979 and Fair 1979). Thus if we call the explanatory expectations the 'input expectations' and the model's solved values as 'output expectations' then a RE solution to the model is found when input expectations equal output expectations and if output expectations accord with their actual equivalents.

The iteration referred to earlier is then based on adjusting input expectations to be equal to output expectations. This iteration shall be formally defined in a moment.

Model prediction, however, only produces expectations for endogenous variables (such as SC_t , FT_t , FD_t , etc.). Since we have suggested that subjective risk in a RE context is exogenous then the solution procedure leaves risk undetermined.

Subjective risk expectations have therefore to be estimated as an adjunct to the main endogenous expectations. That is, since moving risk is defined as:-

$$E\{(X - E(X))^2\}$$

then the adopted procedure is to generate the endogenous expectation $E(X)$, then form the squared deviation, and then generate the expected values of risk by defining its RE.

Since, by definition, there is no model or economic structure which can be used to estimate exogenous expectations, we simply use past values of the variable itself to predict its future movements. If for example

$$Y_t = \phi Y_{t-1} + \epsilon_t \quad (7.7)$$

where Y_t is exogenous, then the RE of Y_t is

$$Y_t^* = \phi Y_{t-1}^* = \phi Y_{t-1}$$

This is the simplest form of autoregression, but is a sufficient RE predictor if the series for Y_t can be represented as a first-order scheme.

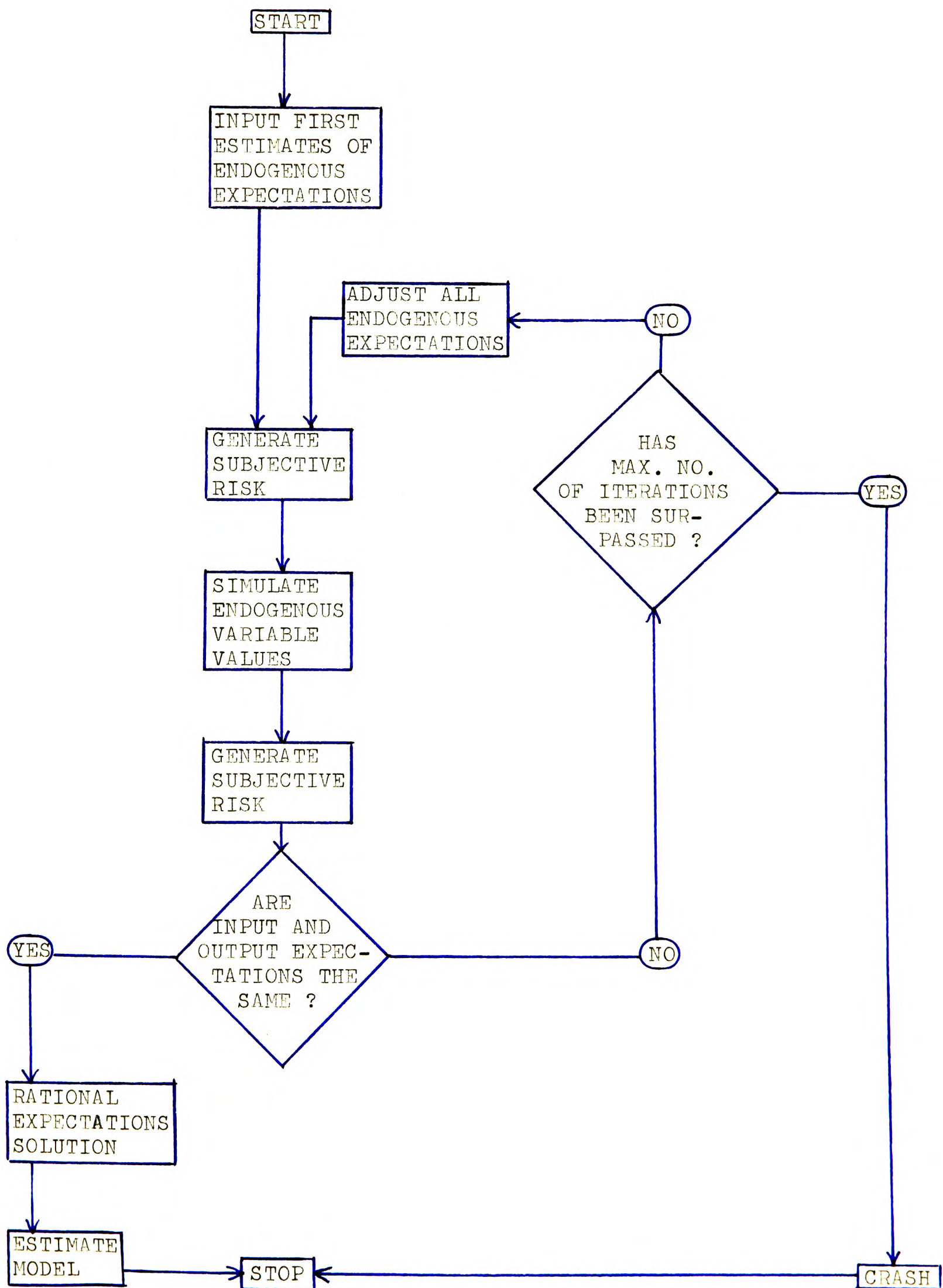
In summary, the RE numerical approach involves

- 1) define the initial estimate of input expectations along with subjective risk expectations
- 2) simulate the model to define output expectations of SC_t , FT_{1t} , FD_{2t} (Q_t and I_t are not required) and redefine subjective risk
- 3) check for convergence: are input and output expectations the same?
- 4) if not, adjust new estimates of input expectations to accord with output expectations
- 5) re-evaluate subjective risk to be used as input expectations
- 6) go back to 2).

When input and output expectations are equal then a RE solution to the model has been found. The process of deriving a RE solution is illustrated diagrammatically in Figure 7.1.

FIGURE 7.1 A FLOW DIAGRAM OF A RATIONAL EXPECTATIONS

NUMERICAL SOLUTION



We formally define the convergence criterion for the Re solution as:

$$|X_I - X_O| < \epsilon$$

where X_I are input expectations and X_O are output expectations. The tolerance level, ϵ , is set by observed variations in the actual data and therefore its exact value varies from expectation to expectation and from model to model. When the difference between output expectations and the actual value equivalent is less than about 5% of the current actual value the expectation is trying to measure then convergence is achieved. But this simultaneously depends on input and output expectations being the same so that a RE solution can be verified. The first convergence criterion (output expectations to actual values) is common to most expectations models whilst the second (input to output expectations) is unique to RE models.

Input expectations are iteratively adjusted to output expectations according to the Jacobi algorithm (Conte and De Boor 1980). Thus if k = iteration number, then the k 'th iteration on expectations is adjusted by

$$E(X_t^k | I_{t-1}) = E(X_t^{k-1} | I_{t-1}) + \beta \{X_t^{k-1} - E(X_t^{k-1} | I_{t-1})\}$$

where β is known as the damping factor (Minford 1978 b) and lies in the positive unit interval. The damping factor acts like the adjustment coefficient in the AE hypothesis and may best be understood in these terms. The value of the damping factor roughly determines the number of iterations it takes for the model to solve: high values, quick convergence; low values, slow convergence. The University of Liverpool economic model (Minford 1980) sets the damping factor at 0.15 whilst Beenstock and Holly (1979) set 0.75. The former claims that a value of 0.15 approximates convergence rates in the economy whilst the latter simply set the damping factor to 0.75 to minimise

the number of iterations. Since the damping factor, in itself, has no implication for the final model solution (for a RE solution is a RE solution which ever the convergence rate as long as convergence occurs along the same dynamic path) then we follow Beenstock and Holly's reasoning and set the damping factor at 0.8 for all model solutions.

The object of the numerical approach to solving RE systems is to find values for expectations which may be regarded as Rational.

7.6.1.2 Uniqueness, Stability and Convergence Revisited

In Sec. 2.4.3 we examined how uniqueness was a serious problem for algebraic solutions to RE systems. Only under saddlepoint stability conditions could a RE solution be verified. If a globally stable situation was found, where every possible solution to the model is convergent, then a uniqueness problem exists for RE.

This difficulty is overcome in a numerical solution framework because uniqueness can be ensured if the model is solved for expectations over time beginning and ending at two fixed points. This is a standard numerical device for solving any solution path for any equation (Conte and De Boor 1980). In our case, the first fixed point is the initial guess at expectation (which is fixed per iteration, but changes between iterations) and the final fixed point is a terminal condition on the dynamic path. The two fixed points at any one iteration represent the solution period. That is, we wish to find Rational Expectations from, say, Jan. 1970 to Jan. 1980. Uniqueness is assumed if the RE solution to the model lies between these two points.

Terminal conditions merely state that at some point the solution for the model must converge to their equilibrium values. The equilibrium value of any expectation is its actual or observed equivalent. In economic terms,

the model must therefore converge at the terminal or equilibrium point for a RE solution to be verified. In this way we ensure that the RE solution does not lead to explosive behaviour which, as was noted in Sec. 2.4.3, is inconsistent with the definition of rationality.

In practice, the terminal conditions are imposed by setting expectations equal to their actual values after some date. For example, if the sample data ranges from January 1970 to October 1980 (quarterly), then a terminal date could be set at January 1977 so thereafter (January 1977 to October 1980) actual values are entered as expectations.

From another point of view, it is seen that terminal conditions are required if forward expectations are a part of the model. The definition of a terminal date then means that the model's solution for expectations at time $t+j$ based on information available at time t ($t > 0$) be equal to the actual or observable equivalent outside the solution period (the period over which expectations are solved: January 1970 to October 1980). If this is not imposed then the end period expectation is left undetermined and hence the model becomes insoluble. If N is the sample size with $t=1, \dots, N$, then without a terminal date of $E(X_{t+j} | I_t) = X$ for $j > 0$ and $t=N-1$ then there can be no model solution for $E(X_{t+j} | I_t)$ for $j > 0$, $t=N$ because there is no model solution outside the solution period.

Thus, the solution period begins in period 1 and extends to the terminal point. But note that the expectation of X , say, made in period 0 for period 1 is also adjusted so that the solved (model prediction) value of X in period 1 equals the expected value of X made in period 0 for period 1. In this way we guarantee that expectations are updated in accordance with the forward-looking nature of RE (Sec. 2.4.3). As the terminal data is approached then expectations generation is forced to comply with the fixed-point and hence uniqueness over the dynamic path is assured. Moreover, the updating procedure aligns

expectations with particularly vigorous movements in the actual data over time. Even though the actual data may be fairly stable to begin with, it may not subsequently be the case; RE then adjusts itself to accommodate these turning points.

In addition to solving the model between two fixed points the model itself was constrained to produce predictions which lie in the region of a RE solution. This turned out to be a numerical necessity but it also has a theoretical justification. Minford (1980) argues that the model must be solved in the region of equilibrium otherwise it may exhibit behaviour which is inconsistent with collective rationality. To be consistent with collective rationality then the model solutions for output expectations in this chapter were constrained to lie within the region of observed variability in the actual data. That is, maximum and minimum values for the actual data were found in the time series and expectations generation was forced to lie within these bounds if they did not already do so (which was usually the case).

Thus, there is no convergence or stability problem in a numerical solution to a RE model because convergence is enforced by the fact that the model must solve for its expectations between two fixed points. Uniqueness is assured because there is generally only one dynamic path between two fixed points and the terminal condition on the model solution guarantees this (Minford 1978 b).

7.6.1.3 The Advantages of the Numerical over the Algebraic Solution

We have stressed that any difficulty which arises as a consequence of the solution requirements in a RE system may be tackled in a numerical framework (e.g. uniqueness). Convergence and stability difficulties were also addressed by the numerical method.

One major difficulty with the algebraic approach is that there is no known method by which analytical solutions can be applied to nonlinear simultaneous systems. Numerical solutions are the only course of action.

By deriving a numerical solution at the structural form (we simulate the structural form to obtain model predictions) we automatically impose the cross-equation restrictions embedded in its simultaneous structure. Thus, all the available information is used given an appropriate simulation methods (Sec. 7.6.3). This is a more difficult task in the algebraic method because typically complicated nonlinear combinations of parameters must be imposed as constraints on the estimation procedure if a full RE solution is to be established. This was illustrated in Sec. 2.4.3 where, to obtain a full RE solution, the parameters of equations 2.22 - 2.24 which occur as coefficients or part-coefficients of more than one variable must be estimated as nonlinear combinations of parameters and not as reduced-form aggregates. That is, the system must be estimated recognising these parameter nonlinearities as constraints to the system.

7.6.1.4 Aggregated Risk and Cross-Equation Restrictions

We again form an aggregated risk variable in the demand equation 7.2 which has a similar reasoning to that already outlined in Sec. 6.5.2. The algebra is exactly the same with the exception of the omission of covariance risk in this chapter which has been explained in Sec. 7.4.1. Thus, we present the variable 'T' in the tables of results to follow to indicate the significance of a 'net marginal profitability' risk variable in the store demand equation.

7.6.2 Exogenous Risk

We have mentioned in Sec. 7.6.1.1 that expected risk must be evaluated as an adjunct to the numerical RE solution procedure. This is because numerical solutions (simulations) only generate expectations for endogenous variables.

Since risk is exogenous (Sec. 7.5) then we must define some other device by which expectations for risk may be established.

Exogenous processes can only be predicted on the basis of some combination of past actual values of themselves. This is self-evident. What is not self-evident is how this should be brought about; that is, what combination?

Simple autoregressions offer an immediate method and is the approach adopted in this work. All risk processes will be based on the following general equation

$$R_{jt}^* = \alpha_0 + \sum_{i=1}^{i=4} \alpha_i R_{jt-i}^* + \epsilon_t \quad (7.8)$$

The choice of the four-quarter lag is arbitrary. All that is required are consistent estimates of subjective risk and this equation will guarantee that. Since the equation is for prediction purposes only then we are not concerned with the statistical significance of the parameter estimates. The fact that some may be insignificant does not affect the consistency of equation prediction because significant coefficient estimates remain unbiased even when irrelevant (statistically insignificant) explanatory variables are included (Kmenta 1971 Sec. 10.4).

The choice of a four-quarter lag assumes that most of the variation in risk is captured within this structure and that it is a sufficient predictor of subjective risk for RE purposes.

The constant term in the equation 7.8 simply reflects the fact that the definition of risk is based on variance which has positive-only values. All constants should therefore be estimated as positive.

It may be reasonably argued that the more general Autoregressive Integrated Moving Average (ARIMA) processes would have produced accurate predictions of subjective risk. This particular approach was followed for some months but without success. The identification procedure of evaluating the degree of autoregression, moving average and differencing was disappointingly inconclusive. In fact, the results indicated that a number of ARIMA models would have been valid representations of stationary stochastic processes of any one of the risk expectations. This is unsurprising given the small data set ($n=31$) since identification is not likely to produce firm results on these grounds. In fact, Granger and Newbold (1977) suggest that identification by formal methods (calculating autocorrelation and partial autocorrelation functions (Box and Jenkins 1976)) should not be undertaken with a data set of less than 50.

It was felt that in the absence of conclusive ARIMA results that the simple autoregression of equation 7.8 would suffice as a RE predictor.

7.6.3 Estimation Procedure

The numerical solution outlined in Sec. 7.6.1.1 is the basis of the results to follow. However, this only defines the model solution that establishes the RE of each endogenous variable (and then defines expected risk). We still have to suggest ways in which the structural parameters are estimated.

Many econometric methods exist by which parameter estimates may be derived from a simultaneous framework. To derive the most efficient estimates it is usually accepted that system methods of estimation (FIML, 3SLS) are preferable. This is because they take account of cross-equation restrictions in the model system when the structural parameters are estimated.

However, these methods unfortunately produced parameter estimates in our models which indicated generally weak simultaneous links between equations. This was reflected in statistically insignificant results on the coefficients of those endogenous variables which also act as explanatory variables (that is, SC, I, FT and FD). The one exception was the level of store imports in the supply equation which was usually statistically well-established. Since the model was felt to be basically sound in its structure it may have been the case that one error of misspecification has resulted in generally weak estimates throughout the system. It is well-known that the consequences of misspecification of one equation will be spread throughout the model when system methods of estimation are employed.

Primarily because the simultaneous links of all of the models were unsupported using FIML and 3SLS it was felt that using Seemingly Unrelated Regression Estimation (SURE) techniques would at least provide reliable parameter estimates whilst accounting for cross-equation correlations in predicted errors (Pindyck and Rubinfeld 1976). In this way simultaneous linkages which feature as part of the error structure increase the efficiency of parameter estimates relative to single equation, OLS-based alternatives.

Thus, all models are estimated using SURE and nonlinearities in the structure of the parameters are accounted for by using ML methods (Kmenta 1971 Sec. 12.3). Nonlinear parameter combinations arise when autocorrelation transformations of the equation systems are undertaken so that autocorrelation coefficients are estimated in conjunction with the structural parameters.

The adoption of SURE procedures does not affect the way in which the RE of variables are formed. These result from model simulation techniques based on Gauss-Seidal solution methods (see App. 5). Initial parameter estimates to define the simulation are established by trial and error to minimise the

number of iterations to be performed. Gauss-Seidal then produces solved values of the endogenous variables (model predictions) which are then used as a basis for defining subjective risk.

7.7 Results and Analysis

The presentation of this section follows that of Sec. 6.6 to enable comparisons with Chapter 6. The basic relationships in the simultaneous models of the store markets are examined. As previously stated, they represent how an econometrician would estimate the models without allowing roles for expectations and risk. The main results are then analysed where conventional and risk estimates of the store demand and supply models are given. The resulting coefficients are then turned into elasticities which completes our research effort.

7.7.1 Basic Relationships

Actual values of variables are substituted for the main expectations and, by definition, risk is no longer relevant: $E[(X - \bar{X})^2] = 0$. The basic models are presented in Tables 7.1 - 7.4 and, as with their counterparts in store demand in Chapter 6, serve as a starting point from which a discussion of the role of expectations and risk may begin.

The dynamic structure of the equations is removed in as much as there are no forward expectations (since their actual, current equivalents are substituted) and no lagged endogenous variables which would impose dynamic adjustment across equations. Thus the models are simplified in this respect although lagged adjustment to the breeding stock is retained in the supply equation to reflect interim (short-term) response in the rearing sector. The models are not primarily meant to reflect long-term response, only that there is no

allowable role for expectations, risk and the dynamic endogenous structure implied by forward expectations as a method of dealing with overlapping (Sec. 7.4.2).

Since the models are not the main purpose of the investigations they shall only be cursorily reviewed. The main analysis will be in relation to the risk and expectations models.

TABLE 7.1 BASIC RELATIONS IN THE STORE BEEF STEERS MARKET

$$\begin{aligned} \frac{\text{Store}}{\text{Supply}} Q_{St} = & -13952.9 - 9.602 SC_t + 0.598 BSUK_{t-1} + 6.996 FD_t \\ & (4028.04) \quad (4.034) \quad (0.336) \quad (5.078) \\ & + 0.791 I_t - 292.740 MB_t \\ & (0.002) \quad (1020.701) \end{aligned}$$

$$\frac{\text{Store Demand}}{Q_{Dt}} = \frac{1987.581}{(1410.952)} - \frac{90.334}{(3647.64)} SC_t + \frac{275.364}{(11156.56)} FT_t - \frac{27.455}{(1115.722)} FD_t$$

$$\frac{\text{Store}}{\text{Imports}} I_t = 16458.5 + 56.046 F I_t$$

$$\frac{\text{Fatstock Price}}{\text{Price}} = 16.242 - 0.075 \text{ TS}_t + 0.002 \text{ DI}_t + 0.1\text{E-}04 \text{ IM}_t$$

$$\frac{\text{Feedgrain Price}}{FD_t} = 30.515 - 0.001 B_t + 0.807 W_t + 0.403 HAY_t$$

(6.379)
(0.121)
(0.145)
(0.205)

	i=1	i=2	i=3	i=4	i=5
j=1	. 0.649 (0.107)	0.527 (0.134)	0.651 (0.106)	0.572 (0.191)	0.353 (0.132)
j=2	. -0.106 (0.102)	-0.128 (0.124)	-0.104 (0.102)	-0.002 (0.102)	0.079 (0.112)

LOG OF LIKELIHOOD FUNCTION = -503.475. SAMPLE SIZE = 31. SURE ESTIMATES.

In this and all other tables, $(i = 1,5; j = 1,2)$ are first and second-order autocorrelation coefficients respectively and are presented only when the appropriate autocorrelation transformation has taken place. The subscripts 'ij' refer to the i'th equation and the j'th autocorrelation coefficient.

The most noticeable aspect of the steers market in Table 7.1 is the significantly incorrect sign on the coefficient of store price in the supply equation. The implication is that higher store prices are associated with fewer store sales. This is the inherent relation of store prices to store market throughput, it would seem, which does not augur well for an analysis of expectations formation and risk perception. However, it may be that the model is fundamentally mis-specified and that the inclusion of a full dynamic structure may alter the nature of the coefficients.

Both supply and demand equations are correctly signed for the remaining variables although they are not particularly significant with the exception of the level of store imports in the supply equation. This is clearly an important aspect of the markets and will be further supported by subsequent evidence.

The remainder of the system adequately reflects store trading relations in the sense that those variables that are correctly signed on a priori grounds are statistically significant, whilst those that are incorrectly signed are insignificant.

TABLE 7.2 BASIC RELATIONS IN THE STORE HEIFERS MARKET

Store Supply	Q_{St}	=	-13597.4 (3748.37)	+	1.887 SC_t (2.628)	+	0.138 $BSUK_{t-1}$ (0.214)	-	5.847 FD_t (3.539)
				+	0.797 I_t (0.015)	-	487.134 MB_t (689.118)		
Store Demand	Q_{Dt}	=	174600 (458995)	+	358.425 SC_t (942.434)	+	1057.168 FT_t (2782.559)	-	98.519 FD_t (274.316)
Store Imports	I_t	=	16662.6 (4706.22)	+	0.829 FT_t (12.836)				
Fatstock Price	FT_t	=	8.729 (11.542)	-	0.076 TS_t (0.018)	+	0.002 DI_t (0.5E-03)	+	0.2E-04 IM_t (0.6E-04)
Feedgrain Price	FD_t	=	27.238 (6.324)	-	0.017 B_t (0.123)	+	0.937 W_t (0.147)	+	0.255 HAY_t (0.206)
			i=1	i=2	i=3	i=4	i=5		
j=1	.		0.577 (0.102)	0.584 (0.168)	0.578 (0.102)	0.694 (0.208)	0.238 (0.146)		
j=2	.		0.020 (0.098)	-0.107 (0.171)	0.021 (0.098)	-0.002 (0.124)	0.093 (0.123)		

Beef heifer results are shown in Table 7.2 and represent a fairly well established system although store price in the demand equation is incorrectly signed. This may be indicative of the influence of the breeding value of heifers in the beef production system. That is, a higher store price in the demand equation may lead to more store heifers being bought because the increased store price also increases the value of female animals through their breeding role. They may be bought-in to the farm to extend the size of the breeding herd and thus any increase in their price indicates a good sale value of any progeny. This explanation relies on the fact that the store market is not distinct in the heifer case which it may not be in reality because of the duality of purpose for which heifers are bought.

The remaining influences that are well defined at this stage are the effects of store imports in the supply equation, total slaughterings and disposable income in the fatstock price equation and the influence of wheat price in the feedgrain price equation. It is to be expected that when the model is re-specified that most, if not all, of the coefficients will change as a consequence of the estimation procedure (because of the adjustment for cross-equation error patterns - Sec. 7.6.3).

TABLE 7.3 BASIC RELATIONS IN THE STORE PIGS MARKET

<u>Store Supply</u>	Q_{St}	=	3558.32 (8371.70)	-	200.633 SC_t (0.072)	-	0.5E-04 $BSUK_{t-1}$ (0.6E-03)	-	120.797 FD_t (24.964)
			+ 0.803 I_t (0.2E-05)						
<u>Store Demand</u>	Q_{Dt}	=	21250 (0.514)	-	200.809 SC_t (0.010)	+	227.912 FT_t (58.437)	-	125.417 FD_t (24.899)
<u>Store Imports</u>	I_t	=	8778.96 (10275)	+	0.601 FT_t (0.048)				
<u>Fatstock Price</u>	FT_t	=	30.721 (1.529)	+	0.5E-05 TS_t (0.8E-04)	+	0.1E-05 DI_t (0.1E-04)	-	0.2E-08 IM_t (0.3E-07)
<u>Feedgrain Price</u>	FD_t	=	42.710 (5.172)	+	0.011 B_t (0.087)	+	0.753 W_t (0.118)		
			i=1	i=2	i=3	i=4	i=5		
j=1	.	0.602 (0.048)	0.602 (0.049)	0.601 (0.049)	0.601 (0.049)	0.709 (0.068)			

LOG OF LIKELIHOOD FUNCTION = -774.669. SAMPLE SIZE = 31. SURE ESTIMATES.

Table 7.3 presents the results for the basic model of the store pig sector. It is clear that the system faces significantly more difficult specification problems than the heifer case.

Store price in the supply equation is again inversely related to total store supply and the significance of the parameter estimate suggests that this fundamental influence is so strong that it is unlikely to change when expectations and risk variables are included. If this is the case then store price must be viewed in terms of its reserve-price role where high store prices are used to finance herd expansion (Sec. 3.2.1). A currently negative store price may indeed be associated with a shortfall of store supply because actual, current store price does not reflect the timing of supplying decisions. That is, in order to determine the current period's store supply, rearing decisions have to be made at least one quarter (3 months) before which set next period's store sales. The fact that current, actual store price is used to partly determine current store supply may not reflect the rearing decision. If it does not, then currently high store prices may act as a motive for the breeding farmer to retain some of his stock so that the breeding herd may be expanded to take advantage of generally higher store prices. The assumption is that the pattern of rising prices should persist, a not unreasonable assumption throughout the 1970's. Without further examination of the role of expectations in store supply no firmer conclusions may be reached.

Mention must also be made of the influence of store imports in the supply equation which seems almost definitional in its significance. This is in line with the previous basic results and reveals the extent to which the demand-orientation of the imports equation is correctly explaining the reasoning behind the import decision. The store demand equation is correctly estimated whilst the fatstock equation contrasts with the rest of the system in that the effects of the explanatory variables seems harder to establish. Finally, the feedgrain price equation has been estimated according to the modelling methodology of Sec. 7.4.1.

TABLE 7.4 BASIC RELATIONS IN THE STORE SHEEP MARKET

Store
Supply

$$Q_{St} = -6438.71 + 73.149 SC_t + 0.501 BSUK_{t-1} + 95.319 FD_t + 0.313 I_t$$

(2945.89)

(123.181)

(0.112)

(43.461)

(0.092)

Store
Demand

$$Q_{Dt} = -11944.44 - 277.778 SC_t + 159.038 FT_t + 149.444 FD_t$$

(3710.277)

(20.177)

(22.958)

(54.009)

Store
Imports

$$I_t = 46.687 + 46.895 FT_t$$

(710.406)

(12.222)

Fatstock
Price

$$FT_t = -16.408 + 0.032 TS_t + 0.001 DI_t - 0.6E-05 IM_t$$

(28.665)

(0.007)

(0.002)

(0.4E-05)

Feedgrain
Price

$$FD_t = 26.594 - 0.031 B_t + 1.041 W_t + 0.077 HAY_t$$

(6.284)

(0.128)

(0.150)

(0.201)

		i=1	i=2	i=3	i=4	i=5
j=1	.	-0.079	0.015	0.351	-0.018	0.253
	.	(0.097)	(0.081)	(0.130)	(0.121)	(0.125)

LOG OF LIKELIHOOD FUNCTION = -1232.05. SAMPLE SIZE - 31. SURE ESTIMATES.

The basic relations involved in the store sheep sector are shown in Table 7.4. The system in general has been estimated on the lines of a priori opinions with only two variables incorrectly signed: total slaughterings in the fatstock price equation and barley price in the feedgrain price equation.

Reasonably efficient standard errors have been produced for most of the explanatory variables with the store supply and demand equations being particularly well-defined. This is important since it is the purpose of the analysis to establish the role of a number of influences on store trading within the wider context of a more general system.

It should also be noted at this point that the estimation procedure is responsible for a number of differences in model results when they should ostensibly appear similar. For example, even though identical feed variables

are used in the two beef models and the sheep system distinctly different results appear in each (Tables 7.1, 7.2 and 7.4). This is due to different errors arising in each model which are contemporaneously adjusted in relation to the complete system (SURE). Furthermore, the beef and sheep models may be using the same data in their respective feed equations but it will be noted that model structure is not always identical. This refers to the estimated autocorrelation structure where a second-order scheme has been assumed in the two beef markets and first-order in the sheep market. These apparent differences in equation estimation which should ostensibly be the same also arise in subsequent models.

With respect to all four markets it must be noted that autocorrelation transformations have been undertaken on each system. First-degree autocorrelated error assumptions have been made in the pig and sheep systems whilst a second-degree assumption has been made in the steer and heifer sectors. The justification for these is embedded within the concept of overlapping in RE systems when one and two-period forward expectations are involved (Sec. 2.4.3). It is obvious that it is the purpose of the above analysis to exclude a role for expectations and risk, but in order to enable comparisons with later results these autocorrelation assumptions have been retained in the basic systems. One thing we can be sure of is that, if the autocorrelation specification is correct, the standard error estimates of the coefficients are asymptotically unbiased.

7.7.2 Results for the Rational Expectations Risk and Conventional Models

This section presents the main results of this chapter. Risk and conventional models for the markets are estimated and, because of constraints on space, are presented as different tables.

TABLE 7.5 A RATIONAL EXPECTATIONS MODEL OF RISK PERCEPTION
IN THE STORE BEEF STEERS MARKET

Store
Supply

$$\begin{aligned}
 Q_{St} = & -10045.4 - 5.034 SC_{4t}^* + 0.052 R_{4t}^* - 2.956 BSUK_{t-1} \\
 & (8284.2) \quad (17.020) \quad (0.139) \quad (5.545) \\
 & + 7.796 FD_t + 0.830 I_t - 4213.24 MB_t - 0.128 Q_{St-1} \\
 & (46.014) \quad (0.013) \quad (10315) \quad (1.545) \\
 & - 0.781 Q_{St-2} \\
 & (1.229)
 \end{aligned}$$

Store
Demand

$$\begin{aligned}
 Q_{Dt} = & 54813.9 - 523.286 SC_t + 181.580 FT_{1t+2}^* - 184.013 FD_{2t+2}^* \\
 & (0.3E+07) \quad (1699.514) \quad (183.168) \quad (609.392) \\
 & + 49.685 R_{1t+2}^* - 11.859 R_{2t+2}^* \quad T \text{ (Aggregated Risk)} = 0.228 \\
 & (168.953) \quad (168.561)
 \end{aligned}$$

Store
Imports

$$\begin{aligned}
 I_t = & 24008.4 - 257.177 FT_t + 0.103 I_{t-1} + 0.013 I_{t-2} \\
 & (6795.9) \quad (134.541) \quad (0.184) \quad (0.093)
 \end{aligned}$$

Fatstock
Price

$$\begin{aligned}
 FT_t = & 24.719 - 0.038 TS_t + 0.001 DI_t + 0.9E-04 IM_t \\
 & (9.902) \quad (0.008) \quad (0.5E-03) \quad (0.5E-04) \\
 & - 0.179 FT_{t-1} - 0.059 FT_{t-2} \\
 & (0.139) \quad (0.093)
 \end{aligned}$$

Feedgrain
Price

$$\begin{aligned}
 FD_t = & 8.839 - 0.033 B_t + 0.700 W_t + 0.074 HAY_t \\
 & (7.872) \quad (0.542) \quad (0.398) \quad (0.172) \\
 & + 0.839 FD_{t-1} - 0.396 FD_{t-2} \\
 & (0.245) \quad (0.195)
 \end{aligned}$$

	i=1	i=2	i=3	i=4	i=5
j=1	0.540 (0.162)	0.915 (0.133)	0.431 (0.189)	0.868 (0.219)	-0.811 (0.278)
j=2	0.061 (0.142)	-0.137 (0.119)	-0.126 (0.144)	-0.086 (0.198)	-0.091 (0.266)

LOG OF LIKELIHOOD FUNCTION = -791.861. SAMPLE SIZE = 31. SURE ESTIMATES.

Since the interim results which are used to form expected risk are not essential to an understanding of the main results they are shown in App. 5 where the interim results for the other models are listed.

The results for the beef steers market in Table 7.5 where the role of risk and expectations is investigated are disappointing. In general, many of the variables have little influence on others in the system when based on statistical grounds alone. More specifically, none of the three risk variables seem to play any decisive role in the market.

As with the basic equations illustrated in Table 7.1 confusing signs appear on some of the coefficients. The most notable anomaly is the negative sign of the coefficient on expected store price in the supply equation. This implies that we have failed to identify distinct supply and demand relations in the store market. Alternatively, one possible view, which was suggested in Sec. 3.2, is that higher store prices are used to finance herd expansion. That is, store sale income may be maintained at a constant level with fewer store sales. The animals that would have otherwise been sold are retained in the herd.

Because the store price expectation is statistically insignificant we cannot attach too much economic meaning to its associated risk, which is insignificant anyway. Any role which risk does play in store steer supply is not decipherable from the statistics presented.

Similarly insignificant results are to be found on the remaining coefficients in the supply equation with the exception of the level of store imports. This is correctly signed and clearly plays an important role in determining the level of store steer supply. Out of all the store markets examined, international trade in store beef cattle is likely to be the most easily discernible in its influence. This is primarily because of historical precedent in trading relations with the Irish Republic and also because the markets are well-regulated in terms of distinct sale-points in the beef production process (Sec. 3.4.1). Store imports then enter the process as

additions to the total level of store supply.

The store steer demand equation reflects the general insignificance of the results in the rest of the system although the signs of the coefficients agree with what has already been established in Chapter 6. That is, expected fatstock and feed prices are correctly signed in relation to store purchases and their associated risks follow the signs of their parent expectations. Subjective fatstock price risk is positive which illustrates the market intervention activities of official agencies throughout the study period (Secs. 3.3 and 4.2.3.). Recall that the fatstock market has been supported and hence the effect of variability (risk) in fatstock prices is to increase the expectation of greater sale revenue from each (marginal) store purchased. Greater variability in prices then results in greater store demand.

The opposite is the case with subjective feed price risk since variability in these prices relative to their expected values increases uncertainty concerning the profitability of each store purchased and hence demand, on average, falls off.

The aggregated risk variable ('I') does not offer any indication as to the risk of general variations in profitability in the feeding sector. It is positive (0.288) which suggests that fatstock risk may be more important than feed price risk but it is too insignificant on which to base any firm conclusions concerning demand-behaviour.

The coefficient on actual store price is correctly signed in the demand equation. In one respect this is an important result because the whole equation system is designed to pivot round this variable. Actual store price is the endogenous variable for which the store demand and supply equations must solve because of the identity of store market throughput in equation 7.6. But these equations are the last to be determined in the Gauss-Seidal

solution procedure as a consequence of the ordering of the simultaneous structure (Sec. 7.4.2). It is important that this variable should be correctly signed because it captures movements in the variables in other parts of the system and therefore indicates how well the rest of the equation structure explains the store trading relations.

However, because the system may be performing well does not guarantee that its components are individually well-defined. This is evidenced in the store imports equation where fatstock price is incorrectly signed and statistically significant. This appears to be a feature of the store beef market in general because a similar result will be observed in the heifers case.

The beef fatstock market is fairly well-defined with the effects of total slaughterings and disposable income being statistically significant and correctly signed. This is not the case with the imports of beef which seems to be associated with greater fatstock demand. Viewed as a causal variable in the equation, the effect of the imports of beef is incorrect on a priori grounds because a greater international supply of meat will tend to reduce domestic fatstock price. However, viewed in terms of 'association' then greater imports of beef may just reflect a vigorous domestic market where demand pressure is currently running high.

The lagged dependent variables in the fatstock equation offer no further information on the structure of the market since they are statistically insignificant.

The feedgrain price equation indicates that wheat price and the one-quarter lagged dependent variable are the main forces in establishing current feedgrain price. It is perhaps the case that wheat price reflects more accurately current grain supply and demand conditions and hence, in this example, reflects on feedgrain prices for beef animals. It is difficult to attribute variations

in the dependent variable to either barley or wheat prices because grain prices, in general, are likely to be highly correlated with one another. In this sense they may be viewed as instruments from which the underlying grain market supply and demand conditions may be established.

The one-quarter lagged dependent variable has a statistically significant influence and is quite responsive with a coefficient of 0.839. Moreover, it should be remembered that any lagged dependent variable may be representative of the relevant elasticity if the coefficient estimate is unbiased. The reasoning behind this is easy to establish. FD_t is the dependent variable; its elasticity with respect to the lagged value of itself which has been estimated with a coefficient of β_{54} is defined as

$$\eta = \beta_{54} \frac{\overline{FD}}{\overline{FD}} = \beta_{54}$$

That is, the elasticity is equal to the coefficient estimate. Thus a figure of 0.839 for the coefficient in the store beef steers example indicates a sizeable response over a three-monthly interval.

Besides the additional lag structure imposed on the equation system in general, all variables have been transformed for an autocorrelated error structure of the second degree. The motives for this have already been discussed in Sec. 7.4.2. First and second-order autocorrelation coefficients are presented in the tables. These parameters have been estimated jointly with the rest of the structural parameters, the combinations of which are the ones which maximise the likelihood function.

Because of the confines of space the conventional counterpart to the risk-based store beef steers system is shown as a separate table in 7.6.

TABLE 7.6 CONVENTIONAL ESTIMATES FOR THE RATIONAL EXPECTATIONS

STORE BEEF STEERS MARKET

Store
Supply

$$Q_{St} = -12552.5 - 16.431 SC_{4t}^* - 0.328 BSUK_{t-1} + 3.669 FD_t$$

$$+ 0.853 I_t - 4.449 MB_t + 0.106 Q_{St-1} + 0.062 Q_{St-2}$$

Store
Demand

$$Q_{Dt} = 132.787 - 16.583 SC_t + 4.859 FT_{1t+2}^* - 2.420 FD_{2t+2}^*$$

Store
Imports

$$I_t = 18255.0 + 61.559 FT_t - 0.164 I_{t-1} - 0.021 I_{t-2}$$

Fatstock
Price

$$FT_t = 48.573 - 0.003 TS_t + 0.3E-03 DI_t - 0.6E-06 IM_t$$

$$- 0.459 FT_{t-1} - 0.145 FT_{t-2}$$

Feedgrain
Price

$$FD_t = 12.145 - 0.225 B_t + 0.614 W_t + 0.061 HAY_t$$

$$+ 0.400 FD_{t-1} + 0.164 FD_{t-2}$$

	i=1	i=2	i=3	i=4	i=5
j=1	. 0.026 .(0.006)	0.189 (0.043)	0.190 (0.053)	0.778 (0.106)	0.069 (0.297)
j=2	.-0.011 .(0.015)	0.049 (0.021)	-0.020 (0.007)	-0.003 (0.079)	0.563 (0.210)

LOG OF LIKELIHOOD FUNCTION = -671.365. SAMPLE SIZE = 31. SURE ESTIMATES.

It would appear that as far as statistical significance of the parameter estimates is concerned that generally superior estimates have been found relative to the risk results. On these grounds alone we are forced to accept that the inclusion of risk variables in the store beef steers market adds nothing to our understanding of response to uncertainty.

However, expectations behaviour does play an important role as evidenced by the significance of expected store price in the supply equation of Table 7.6. This is significantly negative which supports the earlier, risk-based result. It suggests that distinct supply and demand behaviour is hard to detect although this is surprising considering the often central role that store markets play in beef production. The negative coefficient may indicate that few farmers distinctly operate store steer supplying operations in isolation from other aspects of the beef production process (e.g. fattening). The existence of integrated enterprises where a proportion of beef stock are reared and fattened on the farm, or a proportion may be sold as stores, or a proportion of stores may be purchased, may all react in the store market to exacerbate the problems econometricians face in identifying store supply and demand. This is not to say that supply influences do not exist since the remaining variables in the conventional store steer supply equation are all statistically well-defined with the exception of the milk/beef price ratio. Although correctly signed, this variable does not offer additional explanation of store supply. This is another surprising result considering the attention that the mechanism of the milk/beef price ratio receives in the literature. The evidence presented here suggests that its influence is not particularly important in establishing a store supply strategy.

The effect of every other variable, with the exception of the breeding stock, is correctly signed and statistically significant. The only explanation for the negative influence of the breeding stock is that it may react hand in hand with the influence of expected store price although exactly how and to what extent is impossible to verify.

Another important potential influence on the breeding stock is the effect of the two lagged dependent variables representing supply in previous periods. The exclusion of these variables in the basic model (Table 7.1) coincided with a significant and correctly signed coefficient on BSUK. When the lagged

dependent variables are included in the risk results of Table 7.6 then the coefficient on BSUK changes sign. If the lagged dependent variables are causing this effect then it is they, and not BSUK, which represent the influence of the previous or potential supply of stores onto the market. In this case the breeding stock may be associated with a reduction of the breeding part of the farm enterprise in favour of a larger feeding component which is supported by the negative coefficient on expected store price.

The store demand equation is a statistically significant reflection of the risk-counterpart. The role played by expectations behaviour in determining the level of store purchases is certainly decisive. Moreover, we have correctly specified the period for which expectations must be made in order to form accurate views of the likely profitability of the marginal store; that is, a two-period forecast.

The store imports equation is a reversal of its counterpart in the risk system. The clear message is that fatstock price determines the level of store imports with negative (inverse) influences arising from the lagged dependent variables. Fatstock price is the driving force in this equation which is discernable from the significance of its parameter estimate. This particular result lends support to the view that the motivation for importing stores is demand-determined. However, supply influences are accounted for, to an extent, by the lagged dependent variables as it can be seen that they also have significant influences.

Fatstock price is well-established with total slaughterings, disposable income and the imports of beef being correctly signed on a priori grounds. The significant influences which determine feedgrain price represent virtually no change from the risk equations and, therefore, what has already been said is relevant.

TABLE 7.7 A RATIONAL EXPECTATIONS MODEL OF RISK PERCEPTION
IN THE STORE BEEF HEIFERS MARKET

<u>Store</u> <u>Supply</u>	Q_{St}	=	-11202.8 (12966.3)	+	1.610 SC_{4t}^* (25.453)	-	0.128 R_{4t}^* (0.268)	+	0.848 $BSUK_{t-1}$ (11.201)	
			-	33.552 FD_t (79.534)	+	0.823 I_t (0.023)	+	1567.39 MB_t (16434.9)	-	1.602 Q_{St-1} (3.492)
			-	2.577 Q_{St-2} (2.993)						
<u>Store</u> <u>Demand</u>	Q_{Dt}	=	7013.854 (1189.058)	-	74.167 SC_t (69.341)	-	6.316 FT_{1t+2}^* (1189.459)	-	0.929 FD_{2t+2}^* (13.301)	
			+	1.993 R_{1t+2}^* (3.427)	-	1.829 R_{2t+2}^* (1.926)	; T (Aggregated Risk) = 0.569			
<u>Store</u> <u>Imports</u>	I_t	=	9619.55 (10715.8)	-	149.051 FT_t (214.450)	+	0.746 I_{t-1} (1.048)	-	0.014 I_{t-2} (0.855)	
<u>Fatstock</u> <u>Price</u>	FT_t	=	35.826 (14.208)	-	0.052 TS_t (0.012)	+	0.7E-03 DI_t (0.7E-04)	+	0.1E-03 IM_t (0.7E-04)	
			-	0.131 FT_{t-1} (0.174)	+	0.044 FT_{t-2} (0.117)				
<u>Feedgrain</u> <u>Price</u>	FD_t	=	-8.264 (5.506)	+	0.401 B_t (0.252)	+	0.362 W_t (0.188)	+	0.109 HAY_t (0.144)	
			+	0.630 FD_{t-1} (0.143)	+	0.2E-03 FD_{t-2} (0.151)				

LOG OF LIKELIHOOD FUNCTION = -789.545. SAMPLE SIZE = 31. SURE ESTIMATES.
No autocorrelation transformation.

The risk results for the store beef heifers market are shown in Table 7.7.

In a general sense they closely parallel the store beef steers results which is what would be expected, but they also correspond in their statistical insignificance which is their disappointing aspect.

The coefficient of expected store price in the store supply equation is correctly signed and indicates that more store heifers will be sold if a greater return is expected from each sale. Its associated risk is insignificant but is

probably correctly signed on a priori grounds. That is, increased variability in store prices is perceived by rearing farmers to make the sale of stores less likely to be profitable hence supply is held back. The risks involved in mis-estimating store price expectations inhibit store heifer sales because greater price variability is taken to imply that each store sale will make less money than in a risk-free world. This is the influence on store supply that we had set out to measure but the statistical insignificance of the result means that we cannot infer too much.

The effect of the breeding stock is correctly signed and contrasts with the previous result for the store beef steers market. Since heifers are more intimately involved with the breeding herd then we would expect that variations in herd numbers on store supply would be adequately measured. Thus increases in the breeding herd will increase store supply one quarter later. Again, this effect has to be understood jointly with the effects of the two lagged dependent variables which are seen to have negative coefficients. That is, BSUK and the lagged dependent variables in the two beef markets have opposed effects in the supply equations. The lagged dependent variables in the heifer case appear to represent a belief on the part of farmers that over-supply in previous periods may be associated with a relatively weaker market in the current period whilst this is counter-balanced by expectations behaviour on store price. The relative strength of each will then determine store supply strategy on a quarter to quarter basis.

All other variables in the equation are statistically insignificant with the exception, as in the store steer example, of the level of store heifer imports. This is a pleasing result because equations specifying international trading relations are notoriously difficult to econometrically determine as a consequence of the data aggregates with which econometricians are forced to work.

The demand equation indicates that actual store price is doing most of the work in influencing the number of store heifers bought-in. The statistical significance of this variable alone would indicate that no other decision criteria, on which the store purchasing decision is based, are required.

This would seem the most acceptable explanation in the light of the evidence presented because the remaining parameter estimates are only weakly defined. Indeed, expected fatstock price is incorrectly signed and cannot be trusted to establish the influence of its associated risk. If the farmer is unconcerned about expected fatstock and feed prices in general he can hardly be concerned about the risk of mis-estimating them.

The aggregated risk variable, as measured by 'T', provides no further information about the role of risk in store purchasing because the figure, which is a t-statistic, is so low.

No particular variable in the store heifer imports equation indicates that any firm conclusions may be reached. Fatstock price is incorrectly signed on a priori grounds whilst a greater degree of responsiveness appears to emanate from the one-quarter lagged dependent variable. On the one hand this may indicate a steady flow of imported stores the level of which changes little from one quarter to the next. But on the other hand, the effect of the second-quarter lag would suggest that market conditions do change in that a greater level of stores imported in that period would act as a disincentive to import in the current period. Perhaps it takes up to two quarters for store importers to realise that current store market conditions no longer justify importing the same number of stores. The fact that the parameters in the imports equation are insignificantly different from zero implies that conclusions which are drawn from the equation can only be tenuous.

The fatstock price equation is the heifer analogy to the steers equation. This is because the data that enter as explanatory variables are the same. The differences that do occur are due to the dependent variable and as a result of different variables entering the system elsewhere (risk), for instance. Thus, total slaughterings and disposable income are correctly signed in relation to fatstock price as with the steers equation. The level of imported beef is incorrectly signed whilst the two lagged dependent variables are insignificant in their influence.

The feedgrain price equation performs relatively better in statistical terms than its counterpart in the steers market. Both barley and wheat prices are contributing to variations in feed price whilst the first-quarter lagged dependent variable is undoubtedly influencing current prices.

Again, the differences in the feedprice equations between steers and heifers are due to different variables appearing elsewhere in the model. The heifer system, in general, does not provide any firm clues as to how risk may or may not be operating in the store market. Although some influences are well-defined (import levels, fatstock and feed price equations) they occur in sectors of the model which are not of primary concern.

Comparing the risk results of both steers and heifers with those of the demand analysis of Chapter 6 it would appear that if risk is important in the markets then it is the AE hypothesis which goes some way to identifying its influence. However, to what extent risk is identifiable will depend on the forecasting accuracy of the expectations hypothesis employed. It may be the case that subjective risk significantly influences store purchasing decisions because the AE hypothesis is an inaccurate forecasting mechanism. On the other hand, it cannot be ruled-out that the effects of risk will be minimal if accurate RE forecasts are used. This reasoning would suggest itself in the RE store steer results because even though risk was found to be insignificant,

expectations behaviour in the conventionally estimated model revealed in what manner the influence of expectations are important. Risk may have therefore been insignificant in the steers market because rational forecasts of SC_t , FT_t and FD_t are sufficiently accurate so as to rule-out any influence that risk may have had. Is the same pattern observed in the heifers market when it is conventionally estimated? We now turn to these results to answer this.

TABLE 7.8 CONVENTIONAL ESTIMATES FOR THE RATIONAL
EXPECTATIONS - STORE BEEF HEIFERS MARKET

<u>Store Supply</u>	Q_{St}	=	-13306.9 (3409.93)	+	7,178 (0.746)	SC_{4t}^*	-	0.494 (0.255)	$BSUK_{t-1}$	-	22.012 (3.629)	FD_t			
				+	0.847 (0.3E-03)	I_t	+	2286.28 (175.509)	MB_t	+	0.384 (0.070)	Q_{St-1}	+	0.444 (0.039)	Q_{St-2}
<u>Store Demand</u>	Q_{Dt}	=	3039.804 (2631.990)	+	41.949 (1.071)	SC_t	+	14.958 (2.985)	FT_{1t+2}^*	-	5.875 (1.026)	FD_{2t+2}^*			
<u>Store Imports</u>	I_t	=	23854.6 (2773.76)	-	398.446 (3.557)	FT_t	+	0.413 (0.091)	I_{t-1}	-	0.053 (0.040)	I_{t-1}			
<u>Fatstock Price</u>	FT_t	=	31.803 (1.880)	-	0.012 (0.6E-03)	TS_t	+	0.1E-01 (0.2E-04)	DI_t	+	0.8E-05 (0.2E-05)	IM_t			
				-	0.160 (0.045)	FT_{t-1}	+	0.164 (0.025)	FT_{t-2}						
<u>Feedgrain Price</u>	FD_t	=	22.032 (6.838)	+	0.371 (0.086)	B_t	+	0.346 (0.115)	W_t	+	0.186 (0.046)	HAY_t			
				+	0.626 (0.003)	FD_{t-1}	-	0.382 (0.035)	FD_{t-2}						

	i=1	i=2	i=3	i=4	i=5
$j \neq 1$	. 0.489 .(0.045)	1.019 (0.096)	0.071 (0.111)	0.360 (0.063)	-0.734 (0.188)
$h=2$	.-0.072 .(0.023)	-0.447 (0.057)	0.008 (0.014)	-0.296 (0.025)	1.169 (0.173)

LOG OF LIKELIHOOD FUNCTION = -692.576. SAMPLE SIZE = 31. SURE ESTIMATES

The expectation of store price in the supply equation of the conventional results in Table 7.7 indicate that expectations are influential. The sign of the coefficient is positive which supports the corresponding result in the risk model. Since the conventional estimate is more significant then we must accept this as an accurate description of behaviour in the store markets.

The influences of feed price and the breeding stock in the supply equation are correctly signed on a priori grounds. We have noted that most farmers have available to them the choice of whether or not to sell their stock, and conversely, the effect of store retention (or equivalently, less activity in the store market) may be consequent upon higher feed prices. Higher feed prices may induce less activity because it could be taken to reflect a general decline in the profitability of store production. As a result, some store suppliers, and especially those which have partially integrated rearing and feeding systems, may simply retain their stock realising that store prices are likely to fall because of less market throughput generally.

The influence of the breeding stock is more problematical. It may be associated with the effect of higher feed prices just mentioned, or it may be symptomatic of some force which is exerting an influence from the dairy sector. The latter would seem most likely because a large proportion of beef heifers emanate from the dairy breeding herd (Sec. 3.5.1). However, the sign of the coefficient on the milk/beef price ratio does not suggest straightforward horizontal links between the beef and dairy sectors. It would seem that much of the store supply equation suffers from specification error. This error can only arise as a consequence of the inclusion of expectations and risk variables, for it will be recalled that the basic heifer model presented in Table 7.2 correctly estimated the supply equation.

The effects of expectations in the demand equations are correctly signed and reveals the substantial role that they play with respect to feeding costs.

The risk model for the store pigs market in Table 7.9 presents some statistically significant results for risk. We would expect risk to be an important feature of the market, as was observed in Chapter 6, because of the observed instability of the pig production process (the hog cycle).

The store supply equation has a significantly negative influence from expectations of store price on quantity supplied. It has been previously mentioned that a negative result on this expectation may well indicate that we have failed to identify distinct store supply and demand relationships. Higher expectations of store prices are likely to induce retention of stock for herd expansion purposes, but the overwhelming feeling is that it should lead to increased sales. The fact that this is an expectation which is central to the model (recall that the solution procedure pivots around actual store price; predictions or simulations of this variable then define its Rational Expectation) may result in confused signs elsewhere in the system.

First of all, actual feedgrain price is incorrectly signed in the supply equation but is statistically significant. This cannot be understood in terms of supply alone, for it would be a foolish farmer who reduced store sales because feed prices rose. However, the effect of an increased feedprice may alternatively be viewed as inhibiting activity in the market in general. Higher feed prices may induce a feeling of imminent losses from store production and hence farmers may not offer so many stores for sale because they realise that better returns will be obtained by fattening the stock themselves. This could rely on the rearing farmer having alternative, cheaper feeding sources which are largely independent of concentrate feeding prices. Although this reinterpretation (which was suggested in Sec. 3.2.1) would belie expected response, the statistical significance of the result must force us to question the more obvious explanations.

The remaining variables – breeding stock and store import levels – are correctly signed and well-established in a statistical sense. Breeding stock was recognised as a potentially influential aspect of store supply in Sec. 3.6.1. and evidence was mentioned which supported this view (c.f. Jones 1962). The pig breeding stock acts as a barometer of general profitability in pigmeat production and is fairly responsive to alterations in most components of profitability: Jones (ibid) found an elasticity of between 3-10 of the size of the breeding stock with respect to the level of Government fatstock guarantees.

The level of store imports seems, as with the beef sectors already estimated, to be definitionally true. The result speaks for itself and requires no further explanation to that already given for the beef sectors.

Store demand appears quite anomalous but the statistical significance of each parameter estimate forces us to consider alternative explanations than those which would be reached by a priori reasoning. The whole equation seems to be fitting variations in store demand extremely well. Store price is working as it should and is providing the firmest measure of response in the equation. Expected pig fatstock price is negative which suggests that feeding farmers will purchase less stock as the expectation of higher sale revenue from the marginal animal increases. This effect can be viewed in an analogous manner to the negative feedgrain price effect in the store supply equation. That is, higher expectations of fatstock prices may result in less stores purchased if the higher prices are associated with less market throughput. Store suppliers may be unwilling to offload stock should the possibility for profit-taking exist if they fatten the animals themselves. This explanation relies on the existence of integrated (rearing and feeding) systems which allow alternative production strategies of the kind mentioned to be employed should market conditions change at the fatstock end. Moreover, we have seen from Sec. 3.6.1

that store pig sales and purchases are mainly conducted under private contracts. Only 33% of all store exchanges pass through the store markets. This will imply that store market relations may not be so easily discernible in a simultaneous framework where the specification of a complete system may be a difficult task. It is difficult in the sense that the data which underlie the analysis may not completely reflect the motives which are involved in store sales and purchases.

Contrary to these results, the AE mechanism of Chapter 6 found significantly more conclusive parameter estimates which accord with the reasoning given for the nature of demand response within the context of the feeders' margin. The extension of this analytical approach to the general simultaneous framework did not carry with it the relatively more significant results of Chapter 6.

Expected feedgrain price is also incorrectly signed on a priori grounds although the effect of this variable on store demand must be considered in relation to official policy. Both before 1973 and afterwards the pig industry has, to an extent, been buffeted against feed price changes. The Fatstock Guarantee Scheme had a feed price element in its structure which allowed for, in the guarantee price, changing pig feeding costs (Sec. 3.3). Similarly, the EEC pigmeat regime based on sluicgate prices is partly determined by reference to the world grain situation. This does not entirely explain the positive coefficient on expected feedprice but goes some way in indicating why the coefficient may not be negative.

The two risk variables are significant and illustrate aversity to both fatstock and feed price variations relative to their expectations. These are the first, and certainly the most conclusive, risk results to be established in this chapter.

Variability in both sets of prices is disliked by farmers which they take to be a disincentive to buying store stock. This contrasts with the result of Chapter 6 which showed the coefficient on fatstock price risk to be positive. The contradiction is inevitably due to the differing expectations processes, and the relative accuracy of each will be discussed after all the results for the pig sector have been presented. Aggregated risk supports the effects of the individual components in that farmers are also averse to unforeseen variations in net profitability.

The influence of fatstock price on store imports is statistically significant and correctly signed. This is also the first time we have been able to establish an equation for imports which has results which accord with a priori reasoning. That is, the level of all store imports into the UK are primarily demand determined.

Only total slaughterings and the lagged endogenous variable have significant influences on fatstock price. Disposable income and imported pigmeat do not have discernible effects.

Finally, the feedgrain price equation is correctly specified and statistically well-established. Both barley and wheat prices play distinctive roles in determining pig feed prices which may well be due, post 1973, to the fact that EEC policy ties the CAP pigmeat regime to the international grain market. In this way, domestic, or EEC, pig feed prices are unlikely to be much out of line with international, or third country, prices; if not at the same level, at least moving in sympathy.

The lagged dependent variable also plays a role which indicates a fair degree of response of current feed prices to last quarter's price.

The overall significance of the model would indicate that expectations which have been derived from it may be reliably called 'rational'. Furthermore, because the influence of expectations behaviour is well defined in the system then we are able to identify what role risk is playing in the store market (the parent expectation argument). On a technical point, the market is comparatively simpler in relation to the beef systems because it has not been transformed for autocorrelated errors, although it has the additional lag structure imposed as a result of forward expectations.

TABLE 7.10 CONVENTIONAL ESTIMATES FOR THE RATIONAL EXPECTATIONS
STORE PIGS MARKET

<u>Store Supply</u>	Q_{St}	=	-11926.5 (6102.52)	-	465.459 (7.018)	SC_{4t}^*	+	0.292 (0.240)	$BSUK_{t-1}$	+	0.251 (1.184)	FD_t
												$+ 0.850 I_t$ (0.002)
<u>Store Demand</u>	Q_{Dt}	=	9030.909 (206.48)	-	454.545 (4.796)	SC_t	-	10.909 (2.134)	FT_{1t+1}^*	+	4.682 (0.909)	FD_{2t+1}^*
<u>Store Imports</u>	I_t	=	24756.2 (7158.51)	-	10.194 (3.483)	FT_t	+	0.3E-03 (0.3E-03)	I_{t-1}			
<u>Fatstock Price</u>	FT_t	=	38.039 (11.271)	-	0.003 (0.004)	TS_t	-	0.8E-03 (0.3E-03)	DI_t	-	0.1E-05 (0.1E-05)	IM_t
												$+ 0.407 FT_{t-1}$ (0.131)
<u>Feedgrain Price</u>	FD_t	=	3.256 (4.113)	+	0.197 (0.189)	B_t	+	0.651 (0.152)	W_t	+	0.450 (0.064)	FD_{t-1}

LOG OF LIKELIHOOD FUNCTION = -734.547. SAMPLE SIZE = 31. SURE ESTIMATES.

Turning to the conventional results for the store pigs market presented in Table 7.10 what is immediately noticeable is the large element of agreement with the risk results. There are a few exceptions which will be discussed but it is interesting to observe that the three main expectations do not vary widely from their risk equivalents in coefficient size, significance or direction.

The effects of expected store price in the supply equation remains negative as does expected fatstock price in the demand equation; expected feedgrain price is significantly positive.

There is a general fall in statistical significance of the parameter estimates in both supply and demand equations which is, of course, attributable to the absence of the risk variables. However, this effect is neither here nor there since, to take the example of expected fatstock price in the demand equation, there is virtually no economic difference in interpretation consequent upon the change of the t-statistic of -7.694 in the risk equation to a t-statistic of -5.112 in the conventional equation. The point is that both are highly significant.

Significant differences in the results do arise in the store imports and fatstock price equations. It would be safe to assume that, because of the ordering of the solution procedure (Sec. 7.4.2), the differences in the conventional store import equation from its risk counterpart are due to the changes that have taken place in the conventional fatstock equation.

Thus, we look at the latter first to offer an explanation of the change. The fatstock price equation is not particularly well-defined in statistical terms since the effect of disposable income on the market is incorrectly signed. Total slaughterings and imports of pigmeat are correctly signed but the standard errors of their coefficient estimates do not support any firm economic conclusions.

The main effect which seems to be creating the difference between conventional and risk estimates is that disposable income is significantly altering the structure of estimated response in the fatstock market. This is then translated into the imports equation where fatstock price acts as an explanatory variable. Fatstock price in this equation is incorrectly signed which may have confused

response elsewhere in the system (for store imports then acts as an explanatory variable in the supply equation.) However, the lagged dependent variable in the imports equation, although only weakly defined in terms of the size of its coefficient, is correctly signed and may therefore be counteracting some of the incorrect responses due to negative fatstock price.

These are only tentative conclusions since to be more assertive would require greater statistical significance of coefficient estimates throughout the system, which we do not have available.

The feedgrain price equation in Table 7,10 is a direct reflection of the risk estimate and requires no further discussion than that already offered in relation to the risk system.

The last models to be investigated are the store sheep systems presented in Tables 7.11 and 7.12 to which we now turn

TABLE 7.11 A RATIONAL EXPECTATIONS MODEL OF RISK					
PERCEPTION IN THE STORE SHEEP MARKET					
Store Supply	Q_{St}	=	1126.28 (1613.14)	- 286.953 SC [*] _{4t} (5.856)	- 3373.60 R [*] _{4t} (1076.81) + 0.691 BSUK _{t-1} (0.192)
			28.789 FD ₂ (2.894)	+ 0.065 I _t (0.003)	
Store Demand	Q_{Dt}	=	10069.44 (708.819)	- 357.222 SC _t (0.904)	+ 2.056 FT [*] _{1t+1} (1.076) - 18.319 FD [*] _{2t+2} (3.819)
			- 0.486 R [*] _{1t+1} (0.005)	+ 1.424 R [*] _{2t+1} (0.695)	; T (Aggregated Risk) = -2.058
Store Imports	I_t	=	-13973.5 (23.682)	+ 225.933 FT _t (23.682)	- 0.478 I _{t-1} (0.076)
Fatstock Price	FT_t	=	135.012 (20.581)	- 0.018 TS _t (0.003)	- 0.002 DI _t (0.8E-03) - 0.3E-04 IM _t (0.4E-05)
			+ 0.252 FT _{t-1} (0.115)		
Feedgrain	FD_t	=	-5.207 (4.053)	+ 0.315 B _t (0.140)	+ 0.326 W _t (0.119) - 0,019 HAY _t (0.048) + 0.694 FD _{t-1} (0.019)
			i=1	i=2	i=3 i=4 i=5
	j=1	.	0.150 (0.083)	0.175 (0.083)	0.854 (0.083) 0.016 (0.076) -0.043 (0.079)

The risk equations of Table 7.11 reveal a remarkable turn-round from the results of Chapter 6 where the AE hypothesis did not indicate any firm expectations behaviour (with the exception of expected fatstock price).

Store supply is immediately noticeable with both store price expectation and its associated risk playing influential roles. Expected store price is negative which further supports the market throughput argument for integrated farms mentioned earlier. It is clear that farmers are definitely risk averse to variations in store prices which have not been predicted. This is an interesting result in the sense that the failure of the AE result may have been due to the fact that we had not specified any clear role for supply-side uncertainty. Once this has been specified then the nature of risk in both the supply and demand equations becomes more apparent.

The rest of the store supply equation is specified according to our initial views with every variable (breeding stock, feed price and store imports) being statistically significant. This justifies the more general simultaneous approach to modelling the store sheep market since it has enabled a comparison of the interrelationships of supply and demand in the market.

Store price, expected fatstock price and expected feed price are correctly signed and significantly influence the store purchasing decision in the demand equation. The two associated risk variables are also important. Farmers appear averse to fatstock price risk and the statistical strength of the result indicates that it is a primary cause for concern for store purchasers. This is irrespective of the price supports in the fatstock guarantee scheme.

The risk result for feed is positive which indicates that farmers are prone to purchase more store stock should variability in feed prices away from their expected values increase. This is not immediately understandable in terms of the feeders' margin in which the equation has been specified, but may be a reflection of the relative advantage that sheepmeat production has over alternative farming enterprises on the same farm. That is, because sheep are relatively more able to feed off grass and show a reasonable income at final sale than, say, beef animals then increases in feed prices may be taken as a change in relative profitability in favour of sheep meat production. This view relies on a large proportion of sheep farms also farming beef enterprises which, as it happens, is the usual pairing of farming enterprises should these horizontally integrated systems exist (Sec. 3.7.1). This effect seems more plausible when it is taken into account that the same data is used for feed variables in both the beef and sheep systems (App. 6). Thus, an increase in expected feed price risk may indicate to the farmer that he should re-orientate production strategies in favour of sheepmeat.

The aggregated risk variable suggests that farmers are averse to variations in the net profitability of store fattening. Given the nature of the opposing signs on the coefficients of the risk variables the aggregate result is indicative of the relative dominance that fatstock price risk has on store demand.

The store sheep imports equation is correctly specified and provides further evidence to support the view that store imports are demand determined. The lagged dependent variable, in this case, is also significantly defined and indicates that the previous quarter's supply of imported stores acts as a disincentive to import more in the current period. Because imports are demand-based then they will only be purchased in times of relative prosperity in the sheep markets and when there is a shortfall of domestic supply.

It may be the case that farmers believe that the past history of store imports indicates that strong market conditions are followed by relatively weaker phases when not so many stores are required. The effect of this influence will be counteracted should fatstock market conditions indicate that profits may be made for buying imported stores.

Turning to the determination of fatstock price we see that total slaughterings and imports of mutton and lamb are correctly signed and have significant influences. The effect of disposable income is incorrectly signed on a priori grounds. However, evidence from NEDO (1974) suggests that mutton and lamb is a meat which is consumed by lower income groups. As income increases then consumption of meat turns to poultry, beef and pork. The conclusion is that as disposable income increases then the demand for mutton and lamb tails off which results in relatively lower sheep fatstock prices.

The feedgrain price equation is correctly signed throughout. Both barley and wheat prices have significant influences whilst hay price is defined only on weaker statistical grounds. The equation is uncontroversial and supports the economic explanation given for its role in Sec. 7.4.

TABLE 7.12 CONVENTIONAL ESTIMATES FOR THE RATIONAL EXPECTATIONS

STORE SHEEP MARKET

<u>Store Supply</u>	Q_{St}	=	5009.44 (689.750)	-	340.978 (2.414)	SC_{4t}^*	+	0.303 (0.053)	$BSUK_{t-1}$	-	4.384 (0.637)	FD_t
												$1.044 I_t$ (0.001)
<u>Store Demand</u>	Q_{Dt}	=	9246.575 (486.609)	-	344.575 (0.274)	SC_t	-	0.476 (0.339)	FT_{1t+1}^*	-	0.695 (0.298)	FD_{2t+1}^*
<u>Store Imports</u>	I_t	=	214.357 (319.254)	+	28.858 (0.325)	FT_t	+	0.002 (0.001)	I_{t-1}			
<u>Fatstock Price</u>	FT_t	=	108.924 (6.963)	-	0.001 (0.6E-03)	TS_t	+	0.4E-05 (0.3E-03)	DI_t	-	0.002 (0.6E-05)	IM_t
												$- 0.001 FT_{t-1}$ (0.012)
<u>Feedgrain Price</u>	FD_t	=	-0.275 (4.520)	+	0.323 (0.126)	B_t	+	0.201 (0.115)	W_t	+	0.0026 (0.026)	HAY_t
												$+ 0.689 FD_{t-1}$ (0.041)

LOG OF LIKELIHOOD FUNCTION = -420.058. SAMPLE SIZE = 31. SURE ESTIMATES.

No autocorrelation transformation.

The conventional system, as a whole, is not so well-based in econometric terms as its risk counterpart. An overall view would suggest that the latter is a more accurate specification of the store sheep market. For instance, the role of feed price is incorrectly signed in the conventional supply equation. Similarly, the role of expected fatstock price in the store demand equation is incorrectly signed and statistically insignificant whereas its role was correctly estimated in the risk system.

Store and expected feed prices in the demand equation are both correctly defined in the conventional case whilst the rest of the system roughly follows the pattern of events already described.

Returning to the supply equation in the conventional case we see that the significance of the coefficient of expected store price increases when risk is omitted. This is reflected in a general increase in significance throughout the equation, particularly in the effect of store imports. The point to notice is that this would be a perfectly adequate representation of store sheep supply on any grounds, yet we have seen that the influence of a significant risk variable reduces the significance of the other parameter estimates. The implication is that a misleading impression of the accuracy of the results, and hence the conclusions drawn, would arise should only the conventional system be examined. We have provided evidence, in this instance, that the absence of important risk variables in econometrically estimated equations where expectations play a role does bias the remaining parameter estimates. On empirical grounds, parameter estimates will almost always change when additional and significant risk variables are introduced and hence should be accepted as a routine part of econometric investigations.

7.7.3 Elasticity Estimates

Estimates for the elasticities for the parameters of the four models estimated are now presented. All figures are based on the means of the data which are presented in App. 6.

The elasticity estimates presented in Table 7.13 must be considered in relation to the statistical significance of the structural parameters from which they have been derived. The organisation of the presentation should be fairly understandable. An elasticity can only be produced for an explanatory variable; therefore, each elasticity represents the extent of response of a variable in an equation to either one of the following:

Q_{St} , Q_{Dt} , I_t , FI_t and FD_t . From top to bottom the results read: supply equation, demand equation, imports, fatstock price and feedgrain price.

TABLE 7.13 ELASTICITY ESTIMATES FOR ALL MODELS ESTIMATED AT THE MEAN

	STEERS			HEIFERS			PIGS			SHEEP		
	R	C		R	C		R	C		R	C	
SC_{4t}^*	-0.725	-2.376		0.320	1.428		-1.163	-1.069		-0.398	-0.474	
R_{4t}^*	0.054			-0.418			-0.254			-0.177		
$BSUK_{t-1}$	-3.073	-0.476		1.934	-1.127		0.254	0.047		0.659	0.289	
FD_t	0.951	0.447		-6.321	-4.216		-0.069	-0.005		0.343	-0.052	
I_t	22.544	23.169		20.606	21.207		6.231	6.225		0.034	0.549	
MB_t	-1.842	-0.002		0.865	1.261							
Q_{st-1}	-0.128	0.016		-1.602	0.384							
Q_{st-2}	-0.781	0.062		2.577	0.444							
SC_t	-5.684	-2.417		-15.273	8.567		-0.989	-0.939		-0.488	-0.485	
FT_{1t+j}^*	9.465	0.015		-0.487	0.028		-0.099	-0.077		0.021	-0.2E-04	
FD_{2t+j}^*	-23.040	-0.018		-0.183	-0.028		0.111	0.086		-0.218	-0.2E-04	
R_{1t+j}^*	6.212			0.412			-0.003			-0.003		
R_{2t+j}^*	-6.330			-1.619			-0.022			0.068		

	STEERS			HEIFERS			PIGS			SHEEP		
	R	C		R	C		R	C		R	C	
FT _t	-0.495	0.118		-0.278	-0.743		0.045	-0.011		4.591	0.586	STORE IMPORTS
I _{t-1}	0.103	-0.164		0.746	0.413		-0.5E-04	0.3E-03		-0.478	0.003	
I _{t-2}	0.013	-0.021		-0.012	-0.053							
TS _t	-0.331	-0.020		-0.463	-0.099		0.369	-0.123		-0.246	-0.014	
DI _t	0.557	0.167		0.402	0.108		-0.056	-0.445		-0.853	0.586	FATSTOCK PRICE
IM _t	0.061	-0.4E-03		0.070	0.006		0.001	-0.002		-0.088	-0.008	
FT _{t-1}	-0.179	-0.459		-0.131	-0.160		0.249	0.407		0.252	-0.001	
FT _{t-2}	-0.059	-0.145		0.044	0.165							
B _t	-0.018	-0.119		0.213	0.198		0.126	0.095		0.168	0.172	
W _t	0.436	0.363		0.230	0.220		0.328	0.374		0.207	0.128	
HAY _t	0.019	0.015		0.283	0.048					-0.005	0.007	FEEDGRAIN PRICE
FD _{t-1}	0.839	0.400		0.630	0.626		0.475	0.451		0.695	0.689	
FD _{t-2}	-0.396	0.164		0.2E-03	-0.382							

Note: j = 2 for the beef models and j = 1 for the pigs and sheep models

We will draw attention to the elasticity estimates for all expectations and risk variables and mention the more outstanding results in the other variables.

More than proportional response of store supply to changes in expected store price is observed in the store pig sector. A substantial figure has also been derived for the steers sector. At the risk of stating the obvious, the indications are that farmers are aware of the market conditions in which they operate, and since expectations formation is based on the market in general, then farmers utilise what information is available in order to decide on the degree of response to expected store price. This is the essence of a Rational Expectation: that farmers utilise the available information.

Risk response to expected store price is a variable feature throughout the markets. The absolute size of the elasticity estimates appears to have an inverse relation to the absolute size of its parent expectation elasticity estimate. Thus, we observe substantial response to store price expectation in the pigs and steers sectors whilst only fairly minor adjustment occurs to risk. Conversely, less than full adjustment in the heifer and sheep sectors is associated with relatively greater response to risk. This inverse relation is also indicated in the relative percentage response of the risk elasticity estimate to the expected store price estimate for steers, heifers, pigs and sheep respectively: 7.4, 130.6, 0.8E-05 and 44.7. The implication is that the more notice that farmers take of the main expectations effect, the less need there is for a corresponding adjustment to risk. Perhaps farmers forecast more accurately if they are responsive to the main expectations and hence the role of risk is minimised.

Elasticity estimates for expected fatstock price in the steers sector is very large (9.465) whilst the remainder in the other markets are small. This pattern is also observed for the elasticity estimates of expected feed price. It must be recalled, however, that the steers elasticity estimates are derived from parameters which are statistically insignificant. Thus, the true nature of response to expected fatstock and feedgrain prices throughout the models is probably more accurately reflected in the heifers, pigs and sheep results.

In these cases response is generally small but the conventional counterparts indicate that substantial change may occur when risk is omitted from the estimation procedure. In the sheep equations, the conventional estimates for expected fatstock and feed prices are 1000 and 10000 smaller than their risk equivalents. Since expectations behaviour in the store sheep demand equation was found to be particularly significant then the inclusion of risk variables certainly indicates a greater, and more accurate, estimate of response.

The corresponding risk elasticity estimates in all four markets to expected fatstock and feedgrain prices is again a variable feature. Although response in the steers market is large we must ignore the figure on the grounds of the statistical insignificance of the underlying parameter estimates.

The only reliable risk elasticity estimates are to be found in the pig and sheep systems where response is noticeably sluggish. Perhaps the indication is that farmers are aware of expectations processes affecting store demand but that the corresponding influence of risk is again minimised in an analogous manner to the store price expectation/risk argument mentioned above.

The relative percentage response of risk to the main expectation estimates for fatstock and feed prices in the pigs and sheep sectors are 22 and 14 for fatstock prices and 19 and 31 for feed prices. This is fairly sizeable and indicates the order of magnitude of the effects of risk for every change in store purchasing strategy which is based on fatstock and feedgrain price expectations.

One point that should be mentioned is the relative size of the pig fatstock price risk elasticity between the AE approach (12213) and the RE approach (-0.003). The difference is indeed wide and is explained as a result of the differing expectations hypotheses used. The AE estimate may be large because AE is an inaccurate forecasting mechanism. On the other hand, the RE estimate may be incorrect because we have mis-specified the model structure from which expectations are derived. Since both elasticity estimates are based on statistically significant parameter estimates then the relative veracity of each can only be assessed within the general context of the results as a whole (for all of the equation in the AE approach and for all of the model in the RE approach). The indications are that the RE estimate is likely to be more accurate because

- a) a figure of 12213 for the elasticity in the AE model is unlikely in reality
- b) the RE model is more general.

The remaining elasticity estimates are shown for the record. However, it is interesting to note the influence of store imports on the level of store supply. This is more than proportionately responsive in every sector except sheep. Elasticity estimates range from 35 in the risk heifers equation to 6 in the pigs equations. Moreover, there is no noticeable change between risk and conventional estimates suggesting that the numbers imported are not subject to any subjective risk influence that we have defined.

It has already been mentioned that the influence of store imports has been one aspect of the analysis which has been surprising. International trade equations are notoriously difficult to econometrically define yet we have found, time after time, that the influence of stores imports has always been significant.

7.8 Conclusions

Much space has been devoted to explaining how store markets may be modelled in a simultaneous framework, how rational expectations are derived and in what manner subjective risk has been defined. It was no easy task since the solution and estimation methods are complex. What we have found is that risk based on RE is not a significant influence in both beef markets examined. The store pigs market indicated that demand risk may be important whilst the most robust results appeared in the store sheep sector which illustrated, along with store demand risk, that supply risk is a substantial component of store sheep supply. The results, in that sense, have only been partially successful; but we have to be careful in what we mean by success. Success is not defined as establishing statistically significant influences of expectations and risk when there is no real role for their influence in reality. In this case, the successful answer is to show that risk is unimportant. Conversely, success is not defined when insignificant estimates have failed to identify risk when it is important. The remedy then lies in a re-examination of the methodological approach.

What is suggested in the analysis of this chapter is that as long as the investigative approach is founded on a strictly logical base then our results indicate whether the logical approach and reality are related. If they are not, then nothing can be done. If they are, then the results do have some implications for our understanding of the economic environment.

CONCLUSIONS

Throughout this thesis we have attempted to produce results which are consistent with some theoretical base. In this sense, the research effort cannot be viewed without considering the relevant theory. This conclusion attempts to synthesize the work that has been presented and to provide a wider perspective of what has been achieved in leading up to a final assessment.

8.1 Summary of Preceding Chapters

The introduction established the methodological approach adopted in the work and provided a quick guide to the structure of the thesis.

Chapter 2 reviewed alternative ways of evaluating risk and of ordering their potential consequences. It should be clear that risk evaluation and risk ordering are distinct processes, although not entirely mutually exclusive.

Risk evaluation is basically a method whereby risk or uncertainty is measured, or put onto some type of scale. Weighted probabilities or their dispersion may be used, or focus loss and gain calculated, or degrees of belief established. Once risk has been evaluated then it must be related to individual preferences. There are two basic ways in which risk may be ordered: probability and non-probability methods.

The Expected Utility Theorem showed how unique measures may be given to risk once it has passed through, or has been transformed by, an individual's utility function. Risk is then shown as subjective risk since its value

depends on individual preferences. Other ordering methods which use probabilities as their base are stochastic dominance analysis, lexicographic ordering and safety first principles.

The alternative, non-probability approaches rely on more esoteric preference orderings. Subjective risk evaluation within Shackle's focus loss and gain is measured against degrees of potential surprise where surprise functions represent how an individual responds to an uncertain situation. Other non-probability approaches are normally associated with the behavioural school of analysis. It was stated that there is no consistent theoretical approach in this framework and that only ad hoc results could possibly be produced.

Empirical applications of a number of theoretical approaches were then examined. It was argued that, whilst many studies found evidence to support the existence of risk response, support for the theoretical method used was more elusive. Different methods often produced identical conclusions.

Next, expectations theory was linked to the evaluation of risk. 'Moving risk' was defined and two expectations hypotheses investigated. Adaptive expectations was shown to lack theoretical content although it is a popular mechanism among analysts. Its implications were examined within the context of a simple model. Rational expectations had the required theoretical base but is a much more difficult concept to operationalise in econometric terms. Some important theoretical results from recent publications were analysed. Problems typically associated with the RE hypothesis are stability, convergence, uniqueness, autocorrelation (overlapping) and nonlinearities. An algebraic example was investigated which illustrated exactly what is involved in imposing the RE restrictions.

Chapter 3 examined the economic and biological relations in the store markets which provided the empirical base of the thesis. It was shown that official policy, which has been implemented through the Fatstock Guarantee Schemes (and the Milk Marketing Boards) and the CAP of the EEC, is likely to have had an influence on the way risk and expectations behaviour affects the store markets.

The beef, dairy, pigs and sheep markets were then examined in turn and an attempt was made to suggest from where the influence of risk is likely to arise. This chapter provided an approach to modelling the store markets within which the effects of expectations behaviour and risk perception could be observed.

Chapter 4 revealed what theoretical underpinnings are required in order for our empirical results to have economic meaning. The expected utility theorem was adopted and therefore, by implication, the probability approach is used. A variance measure of risk was fully investigated and the theoretical shortcomings and advantages of this choice were outlined.

We then looked at how store markets could be analysed and risk be identified within the marginal store animal approach. Constraints on risk perception were investigated and it was decided that official intervention in the fatstock and milk markets is likely to have affected the structure of store demand in the markets studied. Finally, the aggregation question was addressed which showed what assumptions are necessary in order for individual-based measures of risk to be relevant in a market context.

Chapter 5 represented the first empirical set of results and studied the implications of adopting a more intensive fertilisation strategy in relation to the scale of risk associated with grassland output.

In as much as the beef, dairy and sheep systems are based on ruminant stock then the analytical approach in this chapter had relevance to the store markets. Grassland production is generally the cheapest method by which ruminant stock may be fed and it was the purpose of this chapter to identify to what extent risk is associated with grassland production and to show what relation grassland risk had with increased N fertilisation.

Chapter 6 investigated the role of risk within the context of store demand using the AE hypothesis. Chapter 7 generalised this approach in a simultaneous framework using the RE hypothesis. The structure of both chapters was deliberately made similar to enable comparisons. Thus, the analytical pre-requisites were outlined in each of the Chapters 6 and 7: the definition of risk, modelling approaches, operationalising the theoretical concepts and evaluating the effects of aggregated subjective risk. A basic framework which revealed the relationships between the data sets was estimated in both chapters. It acted as a primer for the analysis to follow and should be understood in this way. The examination of expectations behaviour was then compared to their conventional counterparts which represented how the equations would have been estimated in the absence of risk. The rationale is that the inclusion of significant risk variables materially affects the other parameters in the system. The conventional/risk estimation was undertaken to draw out this distinction. Finally, elasticity estimates were produced and the extent of risk response was examined.

8.2 A Final Assessment

Chapter 5 analysed ex post grazing risk. It was ex post in the sense that no subjective preferences or ordering rules were required to undertake the analysis. That is, the analytical approach simply observes reality and measures risk from those observations. If risk is to be used for decision-making then preference orderings must be assumed or defined.

The problem investigated in Chapter 5 was based on the premise that farmers under-utilised grazing resources. Under-utilisation occurred because feeding ruminant stock with concentrates produced results (in terms of milk and liveweight) which are typically more certain in their outcome than allowing animals to depend mainly on grazing.

One way in which this under-utilisation may be overcome is to invest more in Nitrogen (N) fertilisation. It would be relatively cheaper, on average and considering the opportunity costs of employing unused land, than feeding by concentrates. The investigation of experimental evidence by ANOVA methods showed that increased fertilisation is not associated with greater risk in output (as measured by the variances of output). The actual data evidence, although naturally less conclusive in its results for the ANOVA tables, did suggest that the coefficient of variation of output remained fairly constant (for the year by farm interaction) as N input increased.

The basic conclusion in both experimental and actual data is that increased fertilisation does not increase risk, or at least increase proportional to the level of output. By implication, farmers must be averse to some other aspect of grassland production because what the results do say is that aversity to grazing risk associated with increased use of N is unfounded. In other words, even though grassland output could be increased by use of N there are other factors, unmeasured in this analysis, which makes grazing an activity which is associated with risk and consequently leaves resources under-utilised.

The ANOVA results were extended and supported by a regression analysis of the actual data. The purpose of this exercise was to define coefficient estimates of N input - accounting for rainfall, drought and soil conditions when relevant - to correlate with the change in risk on output as farmers move

from using relatively less to more N. The conclusion was that N fertilisation was associated with less variable output throughout the N input range 150–300 kg/ha.

Finally, the overall measures of risk in grassland output were examined in both experimental and actual data. The results showed, in general, that the level of risk showed no clear increase (in both absolute and proportional terms) as N fertilisation increased.

Chapter 6 represented the first major decision-making analysis. Risk was defined in a subjective context and a central role was allowed for expectations formation. The analytical method showed how expectations and risk could be defined and which was consistent with an optimising framework. This was necessary to fit in with the underlying preference theory where utility is maximised.

Moving risk was defined on the basis of the AE adjustment mechanism in relation to store purchasing decisions with store price acting as the dependent variable. The purpose of the investigation was to examine how risk and expectations perception influenced store purchasing activities. The character of the relation between how expectations were defined and on what mechanism the definition of subjective risk was based in relation to expectations formation was outlined in an optimising framework. Optimal AE were found with level and trend adjustments identified for the main expectations; moving risk was established and its single adjustment parameter estimated. With expectations and risk variables generated, the examination of their effects on store price could proceed.

Basic equations were estimated and provided evidence to suggest that farmers are primarily concerned about fatstock prices in the beef steers and heifers,

dairy, pigs and sheep sectors with the exception of pigs where a distinct role for feed costs was observed.

Adjustment parameters were then defined for both level and trend in the expectations mechanism and a level effect for the consequent measure of risk. In general, the results showed normal adjustment rates for levels whilst the adjustment rates for trend were often confused with cyclical variations in the data. Risk adjustment parameter estimates showed a generally small level of response, which was expected, with the exception of fatstock dairy cow risk. Virtually no adjustment was observed in expected fat pig price whilst all feed risks produced results consistent with the scale of their parent level and trend adjustment parameters.

The main store demand equations were estimated treating the store price as the dependent variable and the influence of risk was established in the store markets for steers, beef heifers and young pigs. It was suggested that the dairy and sheep markets were not amenable to the analytical method. However, the main difficulty with the store dairy market is associated with using discrete time when continuous time would be more appropriate. Conventionally estimated equations were presented alongside the main equations and significant differences were observed in relation to the risk results. A particularly important result of this section was in the identification of positive response to fatstock price risk in the store markets for steers and pigs. It was suggested that this was due to official intervention where market supports constrained risk perception, as defined by the AE hypothesis, to be associated mainly with variability above guarantee or intervention prices.

The risk and conventional estimates were then turned into elasticities estimated at the mean of the data. Most results showed sizeable response to expectations behaviour whilst the results on feed prices had a more than proportionate effect on store steers and dairy cattle. The fatstock pig price risk elasticity was estimated as being very large but could not be relied upon to be a unique result. The correct interpretation is that risk response in this equation is substantial.

The RE approach of Chapter 7 treats marketing of store livestock as the dependent variables. A more general model framework was established within which the effects of moving risk, based on RE, were investigated. A major part of the analysis was concerned with providing a realistic model structure from which RE and hence risk could be defined. It will be recalled that since RE is dependent on some economic model that the model should be reasonably accurate in how it reflects store trading relations. The economic theories therefore examined revolved around the model structure, how well it was statistically established, the generation of expectations and risk which may then be called rational, and finally, an analysis of expectations and risk perception in store supply and demand decision-making.

The basic equations revealed relationships amongst the data sets which indicated that the identification of simultaneous relationships in all of the four markets studied might be a problem. This was particularly evident in the results for store steers and pigs.

The main risk and conventional results were then presented. The beef steers and heifer markets are disappointing in their inconclusive effects of expected price risk behaviour. The pig and sheep systems appeared to produce the evidence which established a role for risk based on the RE hypothesis.

Although some signs on the coefficient estimates indicated further problems with statistical identification of economic systems it was felt that simple re-interpretations of some of the influences would adequately reflect the underlying market conditions.

Finally, elasticity estimates were produced and very substantial responses to expectations and risk were found in the steers market (although derived from statistically weak parameter estimates) whilst less vigorous behaviour was observed in the heifers and sheep markets.

In general, the simultaneous approach used in this chapter facilitated a formalisation of the structure of store markets outlined in Chapter 3. This has perhaps led to a greater understanding of some of the mechanisms involved, especially in the role of store imports in every model examined.

The overall impression of this chapter is that the difference in the results of Chapter 6 are significant. This can be put down to the use of different expectations mechanisms and the use of different dependent variables.

As a test of economic theory, the RE approach indicated substantial risk response in the pigs and sheep systems; it appears that RE cannot always deny the existence of risk in these markets even though it is an efficient forecasting method. AE cannot be a test of economic theory but the results of that chapter suggested that risk perception did have an influence on store purchasing decisions in the steers, heifers and pigs systems.

In the final analysis, we have seen how risk may be investigated and have identified the potential sources of uncertainty within the store markets of England and Wales. Although not entirely conclusive, a number of valuable results have been established which may indicate in what direction further studies of risk may prove to be informative.

APPENDIX 1

CHAIN RULE OF FORECASTING

This explanation follows Mosbaek and Wold (1970)

If we require an expectation for Z_{t+3}^* with current information available only up to I_{t-1} and we have specified to us a relation of the form

$$Z_{t+3}^* = \emptyset Z_{t+2}^* \quad (\text{A.1})$$

Then to make this observable all we require is to form a series of difference equations until the mathematical expectation on the RHS of equation A.1 becomes observable (at time $t-1$). So, if equation A.1 is a true representation of expectations forecasting then so are the following equations

$$Z_{t+2}^* = \emptyset Z_{t+1}^* \quad (\text{A.2})$$

$$Z_{t+1}^* = \emptyset Z_t^* \quad (\text{A.3})$$

$$Z_t^* = \emptyset Z_{t-1} \quad (\text{A.4})$$

because $E(Z_{t-1} | I_{t-1}) = Z_{t-1}$

Then by substituting equation A.4 into A.3; then substitute the resulting equation into equation A.2; and the resulting equation of this into equation A.1 we find

$$Z_{t+3}^* = \emptyset^4 Z_{t-1}$$

which provides a rule for defining observable expectation. This 'chain' of events from the expectation at $t+3$ to the observable at $t-1$ shows how the post predicts the future by the Chain Rule of Forecasting.

A.2.1 EXPECTED UTILITY THEORY ASSUMPTIONS

The reader is referred to Hey (1979) for a fuller discussion. These axioms are by no means unique or complete but provide a sufficient view to understanding the conceptual basis of the Expected Utility Theorem.

Assumption 1. Ordering: All potential outcomes of an event may be ordered; that is, if an event X is more risky than an event Y then this will always be known. The assumption also holds for indifference.

Assumption 2. Transitivity: For any three preference orderings A , B and C if A is preferred to B and B to C then A must be preferred to C . The assumption also holds for indifference.

Assumption 3. Continuity: For any two unknown events probabilities (summing to unity) may be attached to either so that the individual is indifferent between them.

Assumption 4. Substitutability (Independence of Irrelevant Alternatives): If A_1 is a range of possible outcomes of an event and a_1 is one of these outcomes then if the individual is indifferent between A_1 and a_1 then a_1 fully specifies the choices involved in A_1 . That is, no other alternatives (a_i , ' i ' not equal to unity) are necessary outcomes involved in the range A_1 .

Assumption 5. Probability: The use of probability theory is valid so that any multi-stage choice is reducible to a single-stage choice by use of conditional probability or otherwise.

Assumption 6. Monotonicity: There is a monotonic (one to one and increasing/decreasing) relation between (increasing/decreasing) preference orderings over risk.

A.2.2 RELATIVE RISK AVERSION AS AN ELASTICITY

Absolute risk aversion is defined as

$$R_A = - \frac{U''(Y)}{U'(Y)}$$

This can be converted into the elasticity of the slope of the utility function by multiplying by a set income (usually the mean). Thus let $g(y) = U'(Y)$; then the elasticity of marginal response is

$$\eta = \frac{dg(y)}{dy} \cdot \frac{\bar{Y}}{g(y)}$$

which is equivalent to

$$\eta = - \frac{U''(Y)}{U'(Y)} \cdot \bar{Y}$$

A.2.3 QUADRATIC UTILITY FUNCTIONS AND THE VARIANCE MEASURE OF RISK

A Taylor's expansion of any differentiable function (in our case a utility function of profit) has the form:

$$U(\pi) = U(\bar{\pi}) + (\pi - \bar{\pi})U'(\bar{\pi}) + \frac{1}{2}(\pi - \bar{\pi})^2 U''(\bar{\pi}) + \frac{(\pi - \bar{\pi})^n U^n(\bar{\pi})}{n!}$$

where differentiation about mean profit, $\bar{\pi}$, is arbitrary.

If the utility function is quadratic then no derivatives beyond the second exist, hence:

$$U(\pi) = U(\bar{\pi}) + (\pi - \bar{\pi})U'(\bar{\pi}) + \frac{1}{2}(\pi - \bar{\pi})^2 U''(\bar{\pi}) \quad A.2.3.1$$

where, for the utility function in question

$$\begin{aligned} U(\pi) &= - (a - b\pi)^2 \\ U'(\pi) &= 2ab - 2b^2\pi \\ U''(\pi) &= - 2b^2 \end{aligned}$$

hence

$$-\frac{U''(\pi)}{U'(\pi)} = \frac{1}{a/b - \pi}$$

Taking expectations of equation A.2.3.1 we have

$$E\{U(\pi)\} = U(\bar{\pi}) + \frac{1}{2}U''(\bar{\pi})E\{(\pi - \bar{\pi})^2\} \quad A.2.3.2$$

noting that

$$E U(\bar{\pi}) = U(\bar{\pi}) \quad A.2.3.3$$

$$U'(\bar{\pi})E(\pi - \bar{\pi}) = U'(\bar{\pi})(\bar{\pi} - \bar{\pi}) = 0 \quad A.2.3.4$$

The second term of equation A.2.3.2 is equal to the variance and, therefore, we assume, equal to risk. The function $E(U(\pi))$ can be then approximated as comprising mean profit and its variance (risk). Thus, to use mean profit and variance implies a quadratic utility function.

It makes no difference to our argument that the Taylor expansion was taken about the mean. We could have used a moving risk formulation by employing an unspecified expectations hypothesis and obtain identical results. Thus, if equation A.2.3.1 was

$$U(\pi) = E\{U(\pi)\} + (\pi - E(\pi))E\{U'(\pi)\} \\ + \frac{1}{2}(\pi - E(\pi))^2.E\{U''(\pi)\}$$

then taking expectations we have

$$E U(\pi) = E\{U(\pi)\} + \frac{1}{2}E\{(\pi - E(\pi))^2\}.E\{U''(\pi)\}$$

and equations A.2.3.3 and A.2.3.4 become

$$E\{E\{U(\pi)\}\} = E\{U(\pi)\}$$

$$E\{(\pi - E(\pi)).E\{U'(\pi)\}\} = E\{(\pi - E(\pi)).E\{U'(\pi)\}\} = 0$$

noting that:-

$$E\{E\{U'(\pi)\}\} = E\{U'(\pi)\}$$

APPENDIX 3

CALCULATION OF UME OUTPUT

UME from all grassland on a farm = ME requirements of livestock
minus ME from purchased concentrates
minus ME from home-grown grain
minus ME from root and forage crops and
purchased fodder
plus ME in conserved grass sold off the
farm adjusted for differences in
stocks at the beginning and at the
end of the recording period.

ME REQUIREMENTS OF LIVESTOCK

1. Dairy Cows

ME allowance for maintenance (MJ/day)

$$M_m = 8.3 + 0.091W \text{ where } W = \text{liveweight (kg)}$$

ME allowance for milk production (MJ/day)

$$M_i = 4.9Y \text{ where } Y = \text{milk yield in kg/day}$$

ME allowance for maintenance and pregnancy (MJ/day) for
the last four months of pregnancy

$$M_p = M_m + 1.13e^{0.0106t}$$

where t = number of days pregnant and $e = 2.718$, the
base of natural logs.

Total ME requirements for Dairy Cows (MJ/day)

$$8.3 + 0.091W + 4.94Y \dots \text{ for 8 months}$$

$$8.3 + 0.091W + 4.94Y + 1.13e^{0.0106t} \text{ for 4 months}$$

* N.B. Allowance made for conception rate of 90%

2. Suckler Cows The 12 month period for suckler cows can be divided as follows:-

- 2 months maintenance only
- 4 months maintenance + pregnancy allowance
- 6 months maintenance + lactation allowance

ME allowance for maintenance (MJ/day)

$$M_m = 8.3 + 0.091W \text{ where } W = \text{average liveweight}$$

ME allowance for milk production (MJ/day)

$$M_i = 4.94Y \text{ as for dairy cows}$$

ME allowance for maintenance and pregnancy (MJ/day)

$$M_p = M_m + 1.13e^{0.0106t} \text{ where } W = \text{average liveweight (kg)}$$

and t = number of days pregnant

Milk Yield - average for all breeds

Month	1	2	3	4	5	6
kg/day	10	10	9	8	7	6

Total ME requirements for suckler cows (MJ/day)

$$8.3 + 0.091W \text{ for 2 months}$$

$$8.3 + 0.091W + 1.13e^{0.0106t} \text{ for 4 months}$$

$$8.3 + 0.091W + 4.94Y \text{ for 6 months}$$

* NB An adjustment must be made for the milk intake of suckler calves. Assuming a conception rate of 90% and a milk conversion rate of 95% then the allowance to be deducted for calves per day for 6 months is given by 0.855 (2.878Y) MJ/day where 2.878 = energy value (MJ/day) of milk

This allows the calves' ME requirement to be computed from birth, otherwise the allowance for milk would be made twice - once for production by the cow and again in the calf's requirement.

A.4.1 THE GENERAL FORMULA FOR $X_{t-i}^+(t-i \geq 0)$

Initial estimates of X_{t-i}^+ are required to begin the iteration 6.15. We have justified the equations for X_{t-1}^+ and X_{t-2}^+ in Sec. 6.5. The general formula of $X_{t-i}^+(t-i \geq 0)$ which holds for all values of $t-i \geq 0$ has the form:

$$X_{t-ij}^+(t-ij \geq 0) = \mu_i = (4\gamma\epsilon)^{-1} \sum_{k=ij}^{k=ij+4} (X_{t-k}^+) \quad \text{A.4.1.1}$$

A.4.2 DERIVATION OF ITERATION 6.15.

The derivation in the text of Sec. 6.5 is complete up to the point where the iteration 6.15 is presented, viz.

$$X_t^+ = V_{1t} + \mu_1 V_{2t} + \mu_2 V_{3t}$$

But this is simply a rearrangement of the iteration 6.11 from which we begin our discussion:

$$X_t^+ = X_t + (\gamma' + \epsilon')X_{t-1}^+ - \gamma'\epsilon'X_{t-2}^+$$

The purpose of this appendix is to fully outline the mathematical procedure employed. We use the example in the text (i.e. for $P/E = 1$), the extension for other examples being straightforward. The general case is extremely cumbersome and does not provide any insight into the mechanics of the mathematical method and is therefore not shown.

The point to emphasise throughout is that 6.11 is not an equation, but an iteration so that it is more accurately written as

$$X_t \leq X_t + (\gamma' + \epsilon')X_{t-1}^+ - \gamma'\epsilon'X_{t-2}^+ \quad \text{A.4.2.1}$$

Now, if we begin the iteration at the first observation $t = 0$ (we begin 'counting' at zero instead of one because it is the standard presentation of these iterations), then iteration A.4.2.1 becomes

$$\begin{aligned} X_0^+ &= X_0 + (\gamma' + \varepsilon')X_{0-1}^+ - \gamma'\varepsilon'X_{0-2}^+ \\ X_0^+ &= X_0 + (\gamma' + \varepsilon')X_{-1}^+ - \gamma'\varepsilon'X_{-2}^+ \end{aligned} \quad \text{A.4.2.2}$$

Since $X_{t-i}^+ (t-i < 0)$ are unobservable then we have to replace them by their estimates from the general formula A.4.1.1. Thus iteration A.4.2.2 becomes

$$X_0^+ = X_0 + (\gamma' + \varepsilon')\mu_1 - \gamma'\varepsilon'\mu_2 \quad \text{A.4.2.3}$$

which is an observable equation for A.4.2.2.

The purpose of the exercise is then to form observable counterparts of iteration A.4.2.2 for all time periods $t = 0, 1, \dots, n$. Thus, we next substitute $t = 1$ into iteration A.4.2.1 and we see that

$$\begin{aligned} X_1^+ &= X_1 + (\gamma' + \varepsilon')X_{1-1}^+ - \gamma'\varepsilon'X_{1-2}^+ \\ X_1^+ &= X_1 + (\gamma' + \varepsilon')X_0^+ - \gamma'\varepsilon'X_{-1}^+ \end{aligned} \quad \text{A.4.2.4}$$

where X_0^+ has already been generated by iteration A.4.2.3 and is substituted into iteration A.4.2.4 to give

$$\begin{aligned} X_1^+ &= X_1 + (\gamma' + \varepsilon')X_0 + (\gamma' + \varepsilon')\mu_1 - \gamma'\varepsilon'\mu_2 \\ &\quad - \gamma'\varepsilon'\mu_2 \\ X_1^+ &= X_1 + (\gamma' + \varepsilon')X_0 + \{(\gamma' + \varepsilon')^2 - \gamma'\varepsilon'\}\mu_1 \\ &\quad - \gamma'\varepsilon'(\gamma' + \varepsilon')\mu_2 \end{aligned} \quad \text{A.4.2.5}$$

We next substitute $t = 2$ into iteration A.4.2.1 and we see that

$$X_2^+ = X_2 + (\gamma' + \epsilon')X_{2-1}^+ - \gamma'\epsilon'X_{2-2}^+$$

$$X_2^+ = X_2 + (\gamma' + \epsilon')X_1^+ - \gamma'\epsilon'X_0^+ \quad \text{A.4.2.6}$$

where X_1^+ and X_0^+ have already been defined by iterations A.4.2.3 and A.4.2.5 so we may substitute these results into iteration A.4.2.6 to give

$$\begin{aligned} X_2^+ = & X_2 + (\gamma' + \epsilon')\{X_1 + (\gamma' + \epsilon')X_0 + (\gamma' + \epsilon')^2 \\ & - \gamma'\epsilon'\}\mu_1 - \gamma'\epsilon'(\gamma' + \epsilon')\mu_2 \\ & - \gamma'\epsilon'\{X_0 + (\gamma' + \epsilon')\mu_1 - \gamma'\epsilon'\mu_2\} ; \end{aligned}$$

$$\begin{aligned} X_2^+ = & X_2 + (\gamma' + \epsilon')X_1 + (\gamma' + \epsilon')^2 X_0 \\ & + (\gamma' + \epsilon')\{(\gamma' + \epsilon')^2 - \gamma'\epsilon'\}\mu_1 - \gamma'\epsilon'(\gamma' + \epsilon')\mu_2 \\ & - \gamma'\epsilon'X_0 - \gamma'\epsilon'(\gamma' + \epsilon')\mu_1 + (\gamma'\epsilon')^2\mu_2 ; \end{aligned}$$

$$\begin{aligned} X_2^+ = & X_2 + (\gamma' + \epsilon')X_1 + \{(\gamma' + \epsilon')^2 - \gamma'\epsilon'\}X_0 \\ & + (\gamma' + \epsilon')\{(\gamma' + \epsilon')^2 - 2\gamma'\epsilon'\}\mu_1 \\ & + \{(\gamma'\epsilon')^2 - \gamma'\epsilon'(\gamma' + \epsilon')\}\mu_2 \quad \text{A.4.2.7} \end{aligned}$$

Despite the awesome character of iteration A.4.2.7 it is, in fact, quite simple. The derivation of subsequent iterations is a matter of continuous substitution. This could go on ad infinitum, but is not necessary. It should be clear, for instance, that a pattern is emerging with respect to the coefficients of the variable X_t and μ_1 and μ_2 which is repetitive. For example, the coefficient on X_1 in iteration A.4.2.7 ($\gamma' + \epsilon'$) was the coefficient on X_0 in iteration A.4.2.5, which was the coefficient on X_{-1} (μ_1) in iteration A.4.2.3. The coefficient is 'moving forward' with the time subscript. This pattern of events, although slightly more complicated, can be observed for the coefficients in the rest of the system. The fact that it is repetitive helps us to redefine the iteration 6.11 to 6.15, or

$$X_t^+ = V_{1t} + \mu_1 V_{2t} + \mu_2 V_{3t}$$

where the V_{it} are defined as

$$\begin{aligned} V_{1t} &= X_0 & t &= 0 \\ &= X_1 + (\gamma' + \epsilon')X_0 & t &= 1 \\ &= X_t + (\gamma' + \epsilon')V_{1t-1} - \gamma'\epsilon'V_{1t-2} & t &> 1 \\ V_{2t} &= (\gamma' + \epsilon') & t &= 0 \\ &= (\gamma' + \epsilon')^2 - \gamma'\epsilon' & t &= 1 \\ &= (\gamma' + \epsilon')V_{2t-1} - \gamma'\epsilon'V_{2t-2} & t &> 1 \\ V_{3t} &= -\gamma'\epsilon' & t &= 0 \\ &= -(\gamma' + \epsilon')\gamma'\epsilon' & t &= 1 \\ &= (\gamma' + \epsilon')V_{3t-1} - \gamma'\epsilon'V_{3t-2} & t &> 1 \end{aligned}$$

The repetition we refer to is that the coefficients of the iteration can be defined in terms of themselves for $t > 1$ (not the variables).

A simple verification of iteration A.4.2.6, for example, would be established by setting $t = 1$ in the above system and substituting the values so generated into iteration 6.16. Thus

$$V_{1t(t=1)} = V_{11} = X_1 + (\gamma' + \epsilon')X_0$$

$$V_{2t(t=1)} = V_{21} = (\gamma' + \epsilon')^2 - \gamma'\epsilon'$$

$$V_{3t(t=1)} = V_{31} = -(\gamma' + \epsilon')\gamma'\epsilon'$$

which on substitution into iteration 6.15 gives

$$\begin{aligned} X_1^+ = & X_1 + (\gamma' + \epsilon')X_0 + \{(\gamma' + \epsilon')^2 \\ & - \gamma'\epsilon'\}\mu_1 - \{(\gamma' + \epsilon')\gamma'\epsilon'\}\mu_2 \end{aligned}$$

which is immediately seen as equivalent to iteration A.4.2.5.

A.4.3 LACTATION STRUCTURE OF THE NATIONAL DAIRY HERD

This table is reproduced from Benyon (1978)

LACTATION STRUCTURE OF THE NATIONAL DAIRY HERD 1976/77
ENGLAND AND WALES

Lactations	% Lactation Structure
1	23.7
2	18.3
3	16.9
4	13.7
5	10.0
6	7.1
7	4.7
8	2.8
9	1.6
10	1.2
	100.0

Source: Benyon 1978

A.5.1 THE GAUSS-SEIDEL SOLUTION TECHNIQUE

Consider the two-equation, nonlinear simultaneous system:

$$x = F(x,y)$$

$$y = G(x,y)$$

Without loss of generality, the equations may be solved iteratively according to:

$$x^{K+1} = F(x^K, y^K)$$

$$y^{K+1} = G(x^K, y^K)$$

which is known as the Gauss-Seidel solution technique (Goldfield and Quandt 1972).

The mechanics of the method involve setting initial values for x^K and y^K and then solving for x^{K+1} and y^{K+1} . The choice of the order of solution is arbitrary in this system, but when exclusion restrictions exist in larger systems (i.e. the system is not fully simultaneous, as in our own case) then ordering rules for deciding which equation to solve first may be employed (Sec. 7.4.2). A Gauss-Seidel solution to the above equations is obtained when changes in the calculated values of the endogenous variables are smaller than some pre-determined convergence criterion (Holden et al 1982)

A.5.2 INTERIM RESULTS FOR EXPECTED STORE, FATSTOCK AND FEED PRICE RISKS

This section of the appendix presents results for the RE predictors of risk variables that enter as explanatory variables in the models. Recall that since risk is exogenous then the RE solution method leaves its value undetermined. The following results represent RE predictors of exogenous risk based on lagged value of themselves.

TABLE A.5.1 INTERIM RESULTS FOR STORE PRICE RISK

	<u>Steers</u>	<u>Heifers</u>	<u>Pigs</u>	<u>Sheep</u>
Constant	657.974 (450.574)	465.970 (250.446)	4.867 (3.651)	9.013 (0.117)
R_{4t-1}^*	0.839 (0.178)	0.835 (0.164)	0.882 (0.173)	0.794 (0.230)
R_{4t-2}^*	-0.049 (0.234)	-0.032 (0.215)	-0.002 (0.232)	-0.171 (0.286)
R_{4t-3}^*	0.144 (0.234)	0.129 (0.214)	-0.139 (0.232)	0.098 (0.279)
R_{4t-4}^*	-0.144 (0.178)	-0.136 (0.164)	0.074 (0.173)	-0.488 (0.317)
$\bar{R}^2$	0.607	0.646	0.642	0.623
DW	1.605	1.702	1.334	2.129

TABLE A.5.2 INTERIM RESULTS FOR FATSTOCK PRICE RISK

	<u>Steers</u>	<u>Heifers</u>	<u>Pigs</u>	<u>Sheep</u>
Constant	68.954 (47.309)	62.895 (43.818)	55.933 (40.139)	19.893 (12.655)
R_{1t-1}^*	0.806 (0.185)	0.808 (0.180)	0.797 (0.171)	0.468 (0.202)
R_{1t-2}^*	0.004 (0.239)	0.057 (0.233)	0.117 (0.217)	0.412 (0.234)
R_{1t-3}^*	0.034 (0.239)	0.009 (0.233)	-0.164 (0.217)	-0.619 (0.264)
R_{1t-4}^*	-0.081 (0.185)	-0.076 (0.180)	0.041 (0.170)	0.304 (0.234)
$\bar{R}^2$	0.607	0.624	0.608	0.704
DW	1.596	1.634	1.347	1.347

TABLE A.5.3 INTERIM RESULTS FOR FEEDGRAIN PRICE RISK

	<u>Steers</u>	<u>Heifers</u>	<u>Pigs</u>	<u>Sheep</u>
Constant	297.499 (198.146)	297.499 (198.116)	296.400 (199.784)	291.523 (198.114)
R_{2t-1}^*	0.911 (0.193)	0.911 (0.194)	0.962 (0.196)	0.935 (0.193)
R_{2t-2}^*	0.043 (0.265)	0.044 (0.265)	-0.056 (0.278)	-0.020 (0.267)
R_{2t-3}^*	0.010 (0.265)	0.010 (0.265)	0.083 (0.275)	0.054 (0.267)
R_{2t-4}^*	-0.132 (0.193)	-0.132 (0.193)	-0.152 (0.196)	-0.135 (0.192)
R_{-2}^2	0.704	0.704	0.709	0.704
DW	1.322	1.332	1.339	1.335

A.5.3 A STEP BY STEP ILLUSTRATION OF A RATIONAL EXPECTATIONS

NUMERICAL SOLUTION

Consider the following model

$$Q_{st} = \alpha_0 + \alpha_1 P_t^* + \alpha_2 X_t + u_{1t}$$

$$Q_{dt} = \beta_0 + \beta_1 P_t + \beta_2 Z_t + u_{2t}$$

$$Q_{st} = Q_{dt} = Q_t$$

X_t and Z_t are exogenous; Q_t and P_t are endogenous. A Rational Expectation is required for $P_t^* = E(P_t | I_{t-1})$.

The solution procedure is characterised by approximations and initial 'guesses' as to parameter values and unknown expectations. We will not in this example consider the complexities of terminal conditions, constraints and fixed-point theorems since they are really an aside to what follows.

The object of the exercise is to

- a) obtain values for P_t^* which we may call 'Rational'
- b) subsequently estimate the model to obtain values for the structural parameters.

Suppose t to extend from $t=1$ to n ; n being sample size. The first step in the solution procedure is to provide initial estimates of the structural parameters. This can either be done on the basis of some prior knowledge of their likely values, or by simple single-equation estimation (ignoring the problems of simultaneity), or by simultaneous estimation (two stage least squares, for example). Before this can be undertaken, however, an initial guess for the values of P_t^* must be

made. On this, we can either set an equilibrium solution at $P_t^* = P_t$, or simply regress

$$P_t = \psi P_{t-1}$$

and generate expectations based on the estimated value of ψ .

There is no hard and fast rule as to how initial parameter estimates and unknown variable values (P_t^*) are set, except perhaps that of expediency. This initial stage of 'guessing' should not affect the final results if the model is stable or forced to stability.

Thus given starting values for the parameters and unknown P_t^* we solve the model over $t=1$ to n . That is, values for the RHS variables in the model are substituted-in for $t=1$ to n and endogenous variable values are calculated. For instance, take the first equation and assume

$$\alpha_0 = 10; \quad \alpha_1 = 0.9; \quad \alpha_2 = 0.6; \quad P_{t(t=1)}^* = 70; \quad X_{t(t=1)} = 50$$

therefore $Q_{st} = 103 = 10 + 0.9 \times 70 + 0.6 \times 50$.

Similarly, P_t is calculated for $t=1$ since it, too, is an endogenous variable. This process is then repeated for $t=2$ to n and thus completes one iteration of the Gauss-Seidel aspect of the solution procedure.

But notice that any value for P_t which is generated from the model's prediction for P_t by the method just described is in fact the model's expectation for P_t ; that is P_t^* . If the model is a fair representation of reality, as it is supposed to be in Chapter 7, then this prediction is a part-rational expectation for P_t (it will be a full rational expectation when the convergence criteria are satisfied).

Expectations of P_t , thus generated, are then adjusted by the Jacobi algorithm (Sec. 7.6.1.1) so that a position of stability in expectations formation is approached. This then completes one iteration of the Rational Expectations aspect of the solution procedure. In addition, the Risk expectations are derived from the predicted values for P_t and these, too, then become subject to the Jacobi algorithm.

On a technical point, it does not matter whether the RE iterative scheme is undertaken first or the Gauss-Seidel since the ultimate object is to achieve stability in the system. A full RE solution will be guaranteed by the imposition of the dynamic and terminal constraints.

At each iteration in the two-part scheme the structural parameters are re-estimated until they become stable in that they change little from one iteration to the next. Once they have become stable then a Gauss-Seidel solution to the system has been found. When expectations have become stable then a RE solution to the system has been found.

The model is then finally estimated to derive structural parameters based on Rational Expectations. In summary, the entire solution procedure is

- a) set initial parameter values
- b) set initial expectation values
- c) iterate the model on a Gauss-Seidel basis
- d) iterate the model on a RE basis (Jacobi algorithm)
- e) re-estimate the model thus defining new parameter values
- f) go back to c) until convergence is achieved.

A.6.1 DATA FOR CHAPTER 5

EXPERIMENTAL DATA: 21 individual site observations. Annual data over 1970-1973, inclusive. All information from ADAS/GRI 1980 (a).

Grassland Output Annual Dry Matter Yield 1970-73, inclusive. Tonnes/ha.

 Data Means at 150 kg/ha N: Pattern 1 = 7.09
 Pattern 2 = 7.40

 Data Means at 300 kg/ha N: Pattern 1 = 10.32
 Pattern 2 = 10.39

Nitrogen Nitrogen Kg/ha.

 Data Means: Set Levels at 150 and 300 Kg/ha N

Sites Each site is representative of an important area of "enclosed" grassland on a well-defined soil series with an elevation below 360 M. 21 sites over England and Wales. Sec. 2.1 ADAS/GRI (a) for further details.

ACTUAL DATA: Individual farm data. 201 farms in total. Three recording periods with two harvest years in each: 1974/76; 1975/77; 1976/78. All data derived from dairy farms. All information from ADAS/GRI 1980 (b).

Grassland Output UME Gigajoules per hectare, divided by area of grass used during the harvest year.

 Data Means: Group 1 = 54.30; Group 2 = 57.85.

Nitrogen Nitrogen Kg/ha.

 Data Means: Group 1 = 205.5; Group 2 = 246.3.

Farms	Farm observations covering England and Wales. No further details given.
Rainfall	Annual average, mm. Data Means: Group 1 = 806.6; Group 2 = 918.4.
Drought Factor	Grass drought factor. Number of days on which the soil moisture deficit exceeds 50 mm. Data Means: Group 1 = 23.0; Group 2 = 22.6.
Drainage Index	Drainage Index is derived by allotting values of 4,3,2 and 1 respectively to the four categories of drainage capability (Explained in Sec. 5.2 and Table 5.1 in thesis), and calculating the area-weighted mean value for all grass fields. High values thus indicate relatively well-drained farms.

A.6.2 DATA FOR CHAPTER 6

All data was deseasonalised and, where appropriate, deflated. Deflation was achieved using the Retail Price Index which is regarded as a more accurate indicator of inflationary pressures. This information also applies to Chapter 7 with the exception of data for Disposable Income which is pre-deseasonalised and deflated. Number of observations differ between Chapters 6 and 7 and is due to differing estimation procedures which have varying costs in the degrees of freedom lost. In addition, data in Chapter 7 was curtailed because of the inadequacies of information from the Overseas Trade Statistics (changing definitions of data). More information in main text. All data refers to England and Wales unless otherwise stated. This also applies to Chapter 7.

BEEF

Store Cattle

1. Steers

Beef Breeds. Steers. Two years old. 2nd Quality Stock. £ per head. Ag. Stats. Data Mean = 145.6.
2. Heifers

Beef Breeds. Heifers. Two years old. 2nd Quality Stock. £ per head. Ag. Stats. Data Mean = 135.9.

Livestock Numbers

1. Steers

Other cattle and calves. One year old and under two. Male (excluding bulls for service). In 000's. Ag. Stats. Data Mean = 568.

Fatstock Price

1. Steers

Fatstock. Average prices. Steers. Medium Weight. Pence per live kg. Certified cattle. Ag. Stats. Data Means: Actual Price = 33.53. Expected Price = 32.22 Associated Risk = 2.32
2. Heifers

Fatstock. Average prices. Heifers. Medium Weight. Pence per live kg. Certified cattle. Ag. Stats. Data Means: Actual Price = 32.00 Expected Price = 33.41 Associated Risk = 2.80

Feed Price

- Steers & Heifers

Compound feedingstuffs. Ex-mill prices: packaging included. 'All Types' average of feed prices. Index, 1975 = 100. Agricultural Price Indices. Great Britain.

Data Means: Steers: Actual Price = 77.87
Expected Price = 72.98
Associated Risk = 4.12
Covariance Risk between Fatstock
and Feedgrain Prices = 3.47

Heifers: Actual Price = 77.87
Expected Price = 77.46
Associated Risk = 4.78
Covariance Risk between Fatstock
and Feedgrain Prices = 4.19

Hay Price

Steers & Heifers Hay prices. Meadow: new. £ per tonne. Prices paid in Eastern Counties. Ag. Stats.
Data Mean = 20.02.

DAIRY

Store Cattle Store cattle. Friesians. 2nd quality stock. Down-Calvers. £ per head. Ag. Stats. Data Mean = 150.2.

Livestock Numbers Heifers in calf: intended mainly for producing milk or rearing calves for the dairy herd. From 'Heifers in calf'. In 000's Ag. Stats.
Data Mean = 505.

Fatstock Prices Average market prices for cattle. Fat cows. £ per head. Based on average fat cow weight of 450 kg. Ag. Stats.

Data Means: Actual Price = 18.45
Expected Price = 17.67
Associated Risk = 150.2
Covariance Risk between Fatstock Price
and Feedgrain Price = 680625.
Covariance Risk between Fatstock Price
and Dairy Cow Price = 1554000.

Feed Prices Compound feedingstuffs. Great Britain. Ex-mill prices: packaging included. Inded, 1975 = 100.

 'For cattle'. Agricultural Price Indices.

Data Means: Actual Price = 68.1
 Expected Price = 56.0
 Associated Risk = 42.69
 Covariance Risk between Feedgrain Price and Dairy Cow Price = 4506.

Dairy Cow Price Milking Cows. Average prices at certain markets.
 Dairy Cattle. Brucellosis accredited and non-accredited. Friesians. Cows in milk. 2nd Class. £ per head. Ag. Stats.
Data Means: Actual Price = 158.2
 Expected Price = 154.1
 Associated Risk = 23.31

PIGS

Store Pigs Store pigs. 6 weeks and under 9 weeks. 2nd quality stock. £ per head. Ag. Stats. Data Mean = 9.33.

Livestock Numbers 'All other pigs'. Under 20 kg. IN 000's. Ag. Stats.
Data Mean = 1791.

Fatstock Price From pigs and sows. Cutters. Fatstock Prices.
 Pence per live kg. Ag. Stats.
Data Means: Actual Price = 32.05
 Expected Price = 29.74
 Associated Risk = 5.86

Feed Prices Compound feedingstuffs. Ex-mill price: packaging included. 'For pigs'. Index, 1975 = 100.

 Agricultural Price Indices. Great Britain.
Data Means: Actual Price = 85.41
 Expected Price = 74.49

Associated Risk = 4.56
Covariance Risk between Fatstock Price
and Feedgrain Price = 0.2E-06

SHEEP

Store Sheep	Store sheep other than hill sheep breeds. Lambs, hoggets, hoggs and tegs. 2nd quality stock. £ per head. Ag. Stats. Data Mean = 10.05.
Livestock Numbers	Total sheep and lambs under one year old. In 000's. Ag. Stats. Data Mean = 2049.
Fatstock price	Sheep. Fat sheep prices. U.K. estimated dressed carcass weight. Pence per live kg. Meat and Livestock Commission Market Survey. Data Means: Actual Price = 63.45 Expected Price = 62.68 Associated Risk = 23.33
Feed Prices	Definition as beef. Data Means: Actual Price = 77.87 Expected Price = 66.99 Associated Risk = 4.02 Covariance Risk between Fatstock Price and Feedgrain Price = 334

A.6.3 DATA FOR CHAPTER 7

BEEF

Store Cattle

1. Steers Beef Breeds. Steers. Yearlings. 2nd quality stock.
£ per head. Ag. Stats.
Data Means: Actual Price = 92.81
Expected Price = 91.83
Associated Risk = 657
2. Heifers Beef Breeds. Heifers. Yearlings. 2nd quality stock.
£ per head. Ag. Stats.
Data Means: Actual Price = 83.00
Expected Price = 80.10
Associated Risk = 465

Breeding Stock

- Steers and Heifers Cows and heifers in milk: mainly for rearing calves for beef plus cows in calf but not in milk: intended mainly for rearing calves for beef.
Ag. Stats. In 000's. Data Mean = 917.

Feedstock Price

1. Steers As Chapter 6
Data Means: Actual Price = 33.53
Expected Price = 33.87
Associated Risk = 80.50

Feed Price

- Steers & Heifers As Chapter 6
Data Means: Steers: Actual Price = 77.87
Expected Price = 79.01
Associated Risk = 337
Heifers: Actual Price = 77.87
Expected Price = 79.03
Associated Risk = 356

Numbers Sold

1. Steers Numbers sold through selected markets. Store cattle. Beef Breeds. Steers. Yearlings. 1st and 2nd quality stock (not separated). Actual numbers used. MAFF Agricultural Market Report. Data Mean = 631.
2. Heifers Numbers sold through selected markets. Store cattle. Beef Breeds. Heifers. Yearlings. 1st and 2nd quality stock. Actual numbers used. MAFF. Agricultural Market Report. Data Mean = 402.

Total Slaughtering

- Steers and Heifers Beef. Steers and Heifers. Total slaughtering. In 000's. MLC Market Review. UK. Data Mean = 288.

Store Imports

1. Steers Non-fat steers and yearling bulls weighing less than 221 kg. and not yet having any permanent teeth. Hundred Kgs. UK. Overseas Trade Statistics. Data Mean = 17139.
2. Heifers Heifers not for dairy purposes weighing less than 221 Kg. and not yet having any permanent teeth. Hundred Kgs. UK. Overseas Trade Statistics. Data Mean = 10065.

Beef Meat Imports

Steers and Heifers

Meat of bovine animals. Fresh, chilled or frozen.
Bone-in. Tonnes. Overseas Trade Statistics.
Data Mean = 22452.

Disposable Income

Steers and Heifers

Personal Disposable Income at 1975 prices. Deflated
by implied consumers' deflator and seasonally
adjusted by Central Statistical Office. Same
definition used for pigs and sheep. CSO Monthly
Digest of Statistics. Data Mean = 18386.

Barley Price

Steers and Heifers

Feeding and milling barley prices. Ex-farm, spot.
£ per tonne. Ag. Stats. Data Mean = 41.48.

Wheat Price

Steers and Heifers

Feeding wheat. Ex-mill or store prices paid to
distributors, dealers, processors or compounders
at the main grain ports of the UK. £ per tonne.
Ag. Stats. Data Mean = 48.77.

Milk Price

Steers and Heifers

Quarterly average net price paid to wholesale
producers in England and Wales. Pence per litre.
UK Dairy Fact and Figures. MMB. Data Mean = 5.42.

Beef Price

Steers and Heifers

Scottish killed sides. Pence per lb. Average of
mean price range quoted each day at Smithfield
Market. Market Survey. MLC. Data Mean = 24.4.
Milk/Beef price ratio data mean = 0.222.

PIGS

Store Price	As Chapter 6. Data Means: Actual Price = 9.33 Expected Price = 10.09 Associated Risk = 4.89
Fatstock Price	As Chapter 6. Data Means: Actual Price = 32.05 Expected Price = 31.20 Associated Risk = 62.51
Feed Price	As Chapter 6. Data Means: Actual Price = 85.41 Expected Price = 80.01 Associated Risk = 324
Breeding Stock	Sows for breeding plus sows and gilts in pig plus other sows for breeding. Ag. Stats. In 000's. Data Mean = 709.
Numbers Sold	Numbers sold through selected markets. Store pigs. 6-9 weeks old. 1st and 2nd quality stock. Actual numbers used. MAFF. Agricultural Market Report. Data Mean = 4349.
Total Slaughtering	Total slaughterings. Pigs. UK. In 000's. MLC Market Review. Data Mean = 1351.
Store Imports	Live swine. Domestic species. Non-breeding animals. Sows of a weight less than 50 kg. Actual numbers used. Overseas Trade Statistics. UK. Data Mean = 318218.

Pigmeat Imports	Meat of domestic seine. Carcasses or half carcasses, with or without heads, feet or flare fat. Fresh chilled or frozen. Kg weight. Data Mean = 47947.
Disposable Income, Barley and Wheat Prices	As Beef, Chapter 7.
SHEEP	
Store Price	As Chapter 6. Data Means: Actual Price = 10.05 Expected Price = 9.00 Associated Risk = 0.34
Fatstock Price	As Chapter 6. Data Means: Actual Price = 63.45 Expected Price = 66.91 Associated Risk = 45.10
Feed Price	As Chapter 6. Data Means: Actual Price = 77.87 Expected Price = 77.11 Associated Risk = 309
Breeding Stock	Ewes kept for breeding plus two-tooth (shearling) ewes to be put to the ram. In 000's. Ag. Stats. Data Mean = 6168.
Numbers Sold	Numbers sold through selected markets. Store Sheep. 1st and 2nd quality stock. Actual Numbers used. MAFF. Agricultural Market Report. Data Mean = 6461.
Total Slaughtering	Total sheep and lambs slaughtered. In 000's. UK. MLC Market Review. Data Mean = 919.

Store Imports	Live sheep. Domestic species. Lambs up to a year old. Overseas Trade Statistics. UK. Data Mean = 3396.
Sheep Meat Imports	Meat of Sheep. Mutton and Lamb. Fresh, chilled or frozen. Kg weight. Overseas Trade Statistics. UK. Data Mean = 173528.
Disposable Income, Barley, Wheat and Hay Prices.	As Beef, Chapter 7.

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